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The Anatomical Structure of Certain Ceylon Woods

BY

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WITH THREE PLATES

INTRODUCTION

The following seven woods of Ceylon, whose anatomical structure is described in this dissertation, form part of a collection of thirty-five specimens of Ceylon woods averaging 2′ 9″ × 3″ × 3″ which were taken by me to the Imperial Forestry Institute, Oxford, in the latter part of April, 1929. Every care was taken to see that the correct species were collected : I regret that it was not possible at the time of collection to obtain herbarium specimens. The woods are those most commonly used in the Island.

The seven woods described are among the most important of this collection. A preliminary description of the thirty-five woods was made. It seemed to me to be more advisable to study the structure of particular families than of individual specimens of several, hence two families, viz., Meliaceae and Tiliaceae were selected. Three specimens of the former and two of the latter were available. In addition to this, one specimen each of two other important families, viz., Moraceae and Sapotaceae has been described.

The macroscopic description has been kept separate from the microscopic description so that it would be of assistance in identification to those without much technical knowledge and without a microscope ; it could easily be followed with the aid of a hand lens and sharp knife.

The weights of the woods were taken from Gamble's *Manual of Indian Timbers* ; lack of sufficient material made it impossible for me to obtain reliable figures of my own ; the weight of *Pityranthe verrucosa* Thw., not being given by Gamble, was calculated by me on one small specimen. All these weights refer to seasoned wood in an air-dry

condition. The terms "hard," "soft," etc., are used with the same meaning as in *British Hardwoods : Their Structure and Identification*, by Chalk and Rendle.

Light	Less than 35 lb. per cubic foot.
Moderately heavy	35-50 lb. per cubic foot.
Heavy	50-60 lb. per cubic foot.

The visibility of the vessels and rays has also been described under the terms used in the above publication with this difference that the names of comparable Ceylon woods have been inserted instead of the names of British woods :—

Vessels.

Very small	Not visible to the naked eye but visible with lens, *e.g.*, *Chloroxylon Swietenia* DC. *Pityranthe verrucosa* Thw.
Small	Barely visible to the naked eye but not distinct. *e.g.*, *Adina cordifolia* Hk.f., *Chukrasia velutina* W. & A.
Moderate size	Clearly visible to the naked eye. *e.g.*, *Acacia leucophloea* Willd.
Large	Conspicuous to the naked eye. *e.g.*, *Dipterocarpus zeylanicus* Thw.

Rays.

Extremely fine	*Adina cordifolia* Hk.f.
Very fine	*Filicium decipiens* Thw.
Fine	*Albizzia Lebbek* Benth.
Moderately broad	*Artocarpus integra* Merr.
Very broad	*Carallia calycina* Benth.

The following terms were used to describe hardness :—

Extremely hard	*Mesua ferrea* Linn.
Very hard	*Manilkara hexandra* Dubard
Hard	*Chukrasia velutina* W. & A.
Moderately hard	*Artocarpus integra* Merr.
Soft	*Nauclea orientalis* Linn. ; *Melia composita* Willd.

In the microscopic description, measurements of vessels were taken from a hundred vessels of each of the following woods :—*Melia composita* Willd., *Azadirachta indica* A. Juss., *Chukrasia velutina* W. & A., *Berrya cordifolia* Burret. Fifty vessels of each of the following woods were measured :—*Artocarpus integra* Merr., *Pityranthe verrucosa* Thw., and *Madhuca longifolia* Macbr. Where possible only single vessels were measured. The figures given for the length of fibres represent the average of 105 fibres taken from macerated material.

The photomicrographs of the woods were taken at a magnification of 10, so that they represent them as seen under a pocket lens.

The amount of material available was unfortunately very limited, and it was therefore unlikely that it would cover the extreme range of

variation in structure within each species due either to external conditions or location in the tree. The figures for measurements should accordingly be accepted with caution. The specimens were taken from the outside of mature trees, and therefore show their mature structure irrespective of external influences.

The botanical names have been revised by Mr. S. D. J. E. Senaratna, Acting Systematic Botanist of the Department of Agriculture, Ceylon.

DESCRIPTIONS OF THE WOODS

MORACEAE

Artocarpus integra Merr.

Kos (S.), *Pillar* (T).

Material—Imperial Forestry Institute Numbers 3801, 3802.

GENERAL PROPERTIES

A moderately hard, moderately heavy wood, weight about 40 lb. per cubic foot. Colour of heartwood yellow, darkening on exposure and age to dark brown.

MACROSCOPIC FEATURES

Growth rings. Indistinct.

Vessels. Moderate size, conspicuous, mostly solitary with occasional groups of 2 and sometimes of 4; not very numerous; fairly evenly distributed throughout the wood, diameter less than the distance between any two rays. Tyloses absent.

Rays. Moderately broad; clear to the naked eye; not numerous; unevenly spaced; on radial section very lustrous; colour golden; moderately distinct on tangential section, about 1 mm. high.

Parenchyma. Paratracheal, completely enclosing the vessels and tending to project tangentially to form short wings; not very abundant.

Ripple marks. Absent.

Resin ducts. None observed.

MICROSCOPIC FEATURES

Vessels. Diameter, tangential 85-175, average 133μ, radial 90-230, average 168μ. Perforations simple, vessel segments straight sided. Pits (*a*) Intervascular pits, numerous with distinct hexagonal borders and clear horizontal elongated mouths; (*b*) vessel-ray and vessel-parenchyma pits large, simple or bordered, round to oblong; mouths when bordered are oval and horizontal.

Rays. 1-4 cells wide rarely 5 cells wide and up to 52 cells high. (The rays seem to be wider on the average in No. 3802 than the rays in No. 3801). Uniseriate rays are not common and consist of vertically elongated cells only ; rays often vertically superimposed and occasionally fused ; heterogeneous, usually one upright cell at the margin as seen in tangential section and a few scattered larger cells on the sides ; pits numerous, simple.

Parenchyma. Pits into rays numerous, simple, round to oval in shape ; pits into vessels semi-bordered on vessel side ; cells short and broad ; on transverse section the cells are slightly larger than the fibres.

Fibres. Thin-walled with wide lumina ; rarely septate, pits scarce except where they cross rays ; when they occur they are simple, slit-like and oblique, on radial walls only ; average length 1,280μ.

MELIACEAE

Chukrasia velutina W. & A.

Hulanhik (S.), *Agalai* (T).

Material—Imperial Forestry Institute Numbers 3795, 758.

GENERAL PROPERTIES

A hard moderately heavy wood, weight about 49 lb. per cubic foot. Colour reddish brown. A distinct satiny lustre is noticeable on both radial and tangential surfaces.

MACROSCOPIC FEATURES

Growth rings. Moderately distinct, marked by a band of parenchyma.

Vessels. Small, barely distinct to the naked eye, mostly in pairs with some solitary vessels and occasional groups of three ; numerous ; fairly uniformly distributed within the growth rings ; diameter less than the width between any two rays. Tyloses absent ; deposits of reddish gum common.

Rays. Fine, barely distinct to the naked eye ; colour of a distinct reddish hue which makes them stand out prominently from the ground tissue ; quite distinct on radial surface owing to their deeper colour ; moderately distinct on tangential surface.

Parenchyma. In unevenly distributed tangential bands and just visible round the vessels.

Ripple marks. Absent.

Resin ducts. Normally absent; one specimen with a single broad row of apparently traumatic ducts (broad white band in photomicrograph).

MICROSCOPIC FEATURES

Vessels. Diameter, tangential 45-170, average 107μ ; radial 40-175, average 119μ. Perforations simple, vessel segments mostly straight sided with oblique ends. Pits (*a*) Intervascular pits, oval, very small, very numerous and bordered but not very distinctly so, with horizontal to oblique narrow mouths which extend the full width of the pits ; (*b*) vessel-ray pits very small, very numerous with faint borders and rather indistinct.

Rays. 1-4 cells wide and up to 22 cells high. (In No. 758 the rays are 1-3 cells wide and up to 19 cells high). Uniseriate rays few and are rarely more than 5 cells high, heterogeneous, the marginal cells consisting of a single row of cells which are higher than the inner cells and shorter radially ; inter-ray pits simple, more numerous on the tangential walls ; cells commonly full of dark gummy deposits ; granular contents are noticeable in some of the marginal and inner cells.

Parenchyma. (1) Paratracheal, not more than 2-3 cells deep ; (2) Terminal, mostly one cell deep ; (3) Scattered parenchyma with long and pointed cells.

Inter-parenchyma pits simple ; pits into vessels not very numerous, bordered, and of irregular shape ; pits into rays simple and round ; crystals common ; cells full of dark gummy deposits.

Fibres. Thick walled, with lumina, which vary in size considerably ; on the cross section, either single or double radial rows of fibres, with lumina which are much wider than the thickness of fibres, are prominent, pits very scarce, oblique and slit-like ; average length 1,280μ.

Melia composita Willd.

Lunumidella (S.), *Malai-vempu* (T).

Material—Imperial Forestry Institute Numbers 3791, 3792.

GENERAL PROPERTIES

A soft light wood, weight about 29½ lb. per cubic foot. Colour of heartwood light red.

MACROSCOPIC FEATURES

Growth rings. Distinct, boundary marked by a ring of large spring wood vessels contrasting with the dense later formed wood.

Vessels. Large, clearly visible to the naked eye, more numerous at the boundary of the growth rings ; mostly solitary but with occasional pairs ; fairly uniform in size ; diameter less than the width between any two rays ; vessel lines distinct on tangential surfaces. Tyloses absent ; deposits of dark gum fairly common.

Rays. Fine, distinct to the naked eye ; regular in size ; distinct on longitudinal surfaces, being darker in colour than the ground tissue.

Parenchyma. (1) As narrow borders round the vessels ; distinct only with lens when wetted ; (2) As faint terminal lines.

Ripple marks. Absent.

Resin ducts. None observed.

MICROSCOPIC FEATURES

Vessels. Diameter, tangential 80-245, average 166μ ; radial 40-270, average 184μ. Perforations simple ; vessel segments barrel-shaped. Pits (*a*) Intervascular pits, moderately small, numerous, borders round, mouths oval, oblique or horizontal, extending the full width of the pits ; (*b*) vessel-ray pits are difficult to observe as the vessels are usually separated from the rays by parenchyma ; (*c*) vessel-parenchyma pits similar in size and shape to intervascular pits.

Rays. Mostly 2-5 cells wide and up to 21 cells high, the higher rays often irregular in shape (T.S.) suggesting fusion of two vertically superimposed rays ; homogeneous, often with a single marginal row of cells which are shorter radially but not appreciably higher than the inner cells; pits on radial walls few and often limited to a single horizontal row ; tangential walls of cells often oblique ; occasional cells filled with dark granular substance.

Parenchyma. (1) Terminal 1-3 cells wide ; (2) Encircling the vessels in a ring 1-2 cells thick and usually separating the vessels from the rays ; tendency to storeyed arrangement. Crystals present in the parenchyma but not abundant.

Fibres. Thin walled with wide lumina; pits scarce, small, slit-like with oblique to vertical mouths ; on cross section either single or more usually double radial rows of fibres, with lumina which are distinctly larger than those of the other fibres, are prominent ; tendency to storeyed arrangement ; average length 990μ.

Azadirachta indica A. Juss.

Kohomba (S.), *Vempu* (T).

Material—Imperial Forestry Institute Numbers 3793, 3794.

GENERAL PROPERTIES

A hard, moderately heavy wood, weight about 47 lb. per cubic foot. Colour of heartwood deep brown to reddish.

MACROSCOPIC FEATURES

Growth rings. Distinct, marked by a broad band of parenchyma.

Vessels. Moderate size, distinct to the naked eye, mostly solitary, with some groups of 2 or 3; fairly numerous ; evenly distributed throughout the wood ; diameter slightly larger than the width between rays. Tyloses absent ; dark gum deposits common.

Rays. Fine, distinct to the naked eye ; unevenly spaced ; clear on radial surface ; indistinct to the naked eye on tangential surface but distinct with lens.

Parenchyma. In broad bands, distinct to the naked eye ; some paratracheal parenchyma present, but not very distinct even with lens.

Ripple marks. Absent.

Resin ducts. None observed.

MICROSCOPIC FEATURES

Vessels. Diameter, tangential 70-260, average 202μ, radial 40-310, average 208μ. Perforations simple ; vessel segments somewhat barrel-shaped with horizontal to oblique ends. Pits (*a*) Intervascular pits, small, very numerous, with distinct borders and narrow slit-like horizontal mouths, tending to coalesce ; (*b*) vessel-ray pits, numerous, half-bordered with narrow horizontal mouths, extending the full width of the borders. Spiral tertiary thickening present.

Rays. 3-4 cells wide and up to 13 cells high ; almost homogeneous, some rays having a single row of marginal cells which are square in shape ; pits very scarce except on end walls ; rays short and spindle-shaped on tangential section.

Parenchyma. (1) In broad terminal bands 4-15 cells wide ; (2) Metatracheal bands of varying depth ; (3) Scattered parenchyma containing crystals, pits into rays simple, small, moderately numerous, both round and oval in shape.

Fibres. Thick walled with little or no lumen ; pits scarce, simple, oblique and slit-like, mostly on the radial walls ; on cross section either single or double radial rows of fibres with large lumina are prominent ; average length 930μ.

TILIACEAE

Berrya cordifolia Burret

Halmilla (S.), *Chavandalai* (T).

Material—Imperial Forestry Institute Numbers 3804, 1393.

GENERAL PROPERTIES

A moderately hard, moderately heavy wood, weight about 49 lb. per cubic foot. Colour of heartwood reddish.

MACROSCOPIC FEATURES

Growth rings. Rather indistinct, marked by fine bands of parenchyma.

Vessels. Very small, indistinct to the naked eye but distinct with lens ; solitary and in groups of 2-4 or more ; very numerous ; evenly distributed throughout the wood ; diameter less than the distance between any two rays. Tyloses present.

Rays. Very fine, barely distinct to the naked eye, unless wetted ; of the same colour as the rest of the tissue but of a slightly deeper shade ; numerous ; visible on radial surface but individual rays not distinct.

Parenchyma. In fine tangential bands 2-4 cells deep ; also diffuse, abundant.

Ripple marks. Present.

Resin ducts. None observed.

MICROSCOPIC FEATURES

Vessels. Diameter, tangential 55-142, average 99μ, radial 56-162, average 112μ. Perforations simple ; mostly straight sided, tendency to be barrel-shaped, with horizontal ends. Pits (*a*) Intervascular pits, small, round, very numerous, bordered, with horizontal to oblique elongated mouths ; (*b*) vessel-ray and vessel-parenchyma pits very small, bordered, with horizontal mouths : varying considerably in size and shape from small and round to large and oblong. Tyloses moderately abundant, with simple pits, often forming septa across the vessels.

Rays. Storeyed ; mostly 2-3 cells wide and from 10-12 cells high ; fusions of the rays of two storeys sometimes occur but are comparatively rare ; a few uniseriate rays are present and they are usually less than 7 cells high ; heterogeneous, with a single row of marginal cells, which are radially higher than the inner cells, and usually contain crystals and gum ; cell to cell pits simple, more numerous on end walls ; gum abundant.

Parenchyma. Storeyed ; pits into rays small openings of irregular size and shape ; inter-parenchyma pits simple.

Fibres. Thin-walled with wide lumina ; pits few, slit-like, simple, more numerous on radial walls ; average length 1,390μ.

Pityranthe verrucosa Thw.

Dikwenna (S.), *Vidpani* (T).

Material—Imperial Forestry Institute Number 3803

GENERAL PROPERTIES

A hard, heavy wood, weight about 59 lb. per cubic foot. Colour of sapwood light yellow, heartwood dark brown.

MACROSCOPIC FEATURES

Growth rings. None discernible.

Vessels. Very small, not visible to the naked eye but distinct with lens ; sometimes solitary but mostly in radial groups of 2-6 or more, groups often joined by parenchyma into tangential or oblique rows ; numerous ; evenly distributed ; diameter less than the distance between any two rays. Tyloses absent.

Rays. Storeyed ; fine, not visible to the naked eye and barely visible even with lens on cross section ; indistinct on radial and tangential surfaces.

Parenchyma. (1) Chiefly vasicentric ; (2) In narrow short metatracheal bands linking up the vessels, sometimes continuous, sometimes broken and oblique and sometimes extending from the vessels as wings.

Ripple marks. Present.

Resin ducts. None observed.

MICROSCOPIC FEATURES

Vessels. Diameter, tangential 30-93, average 65μ. Radial 25-93, average 63μ. Perforations simple ; vessel segments straight sided with

oblique ends. Pits (*a*) Intervascular pits very small, round, very numerous, bordered, with very small oval or horizontal to oblique mouths, borders not very distinct ; (*b*) vessel-ray and vessel-parenchyma pits similar.

Rays. Storeyed ; 1-2, occasionally 3 cells wide and up to 17 cells high ; slightly heterogeneous, 1-2 rows of higher marginal cells which are rarely higher than they are broad ; pits into parenchyma small and round ; inter-ray pits small, round, simple, not numerous.

Parenchyma. Storeyed ; mostly united to the sides of vessels and not completely encircling them ; extending as wings or bands 1-4 cells wide, linking up groups of vessels ; pits not very numerous, small, round to oval, simple.

Fibres. Very thick-walled with very small lumina ; pits very indistinct ; average length 1,460μ.

SAPOTACEAE

Madhuca longifolia Macbr.

Mi (S.), *Iluppai* (T).

Material—Imperial Forestry Institute Numbers 1384, 3806.

GENERAL PROPERTIES

A hard heavy wood, weight about 61 lb. per cubic foot. Colour of heartwood reddish brown.

MACROSCOPIC FEATURES

Growth rings. Indistinct.

Vessels. Small, barely visible to the naked eye, but distinct with lens ; mostly in radial groups of 3-4, occasionally up to 6 ; vessel lines visible to the naked eye but not sharply defined owing to tyloses which are abundant.

Rays. Very fine, distinct only with lens ; indistinct on radial and tangential surfaces ; distance between them less than the diameter of the vessels.

Parenchyma. In fine tangential lines approximately equal to the rays in width and distribution ; visible only with lens.

Ripple marks. Absent.

Resin ducts. None observed.

MICROSCOPIC FEATURES

Vessels. Diameter, tangential 45-170, average 127μ. Radial 70-205, average 128μ. Perforations simple ; vessel segments usually straight sided. Pits (*a*) Intervascular pits, numerous, small, round, with distinct borders which are sometimes hexagonal, and oval to narrow slit-like mouths ; (*b*) vessel-ray pits, numerous, bordered, with narrow horizontal to oblique mouths, also large pits of irregular shape which are also simple or distinctly bordered, the two types often occurring in the same cell ; (*c*) vessel-parenchyma pits similar, some 2-3 times the size of the smaller pits and irregular in shape, both types often present in the same cell ; tyloses present.

Rays. 1-2 cells wide and of various heights owing to the vertical fusions of rays. The larger rays consist of alternate uniseriate and biseriate parts ; heterogeneous, the uniseriate cells being often twice or more times the height of the biseriate cells, the former being square to vertical on radial sections ; pits between cells numerous, very small, simple on both radial and tangential walls ; gummy deposits in cells.

Parenchyma. In very irregular tangential lines, 1-2 cells wide ; inter-parenchyma pits and pits into rays simple and small.

Fibres. Thick-walled with very small lumina ; pits fairly numerous on radial walls, slit-like ; tertiary layer occasionally present in 1384 ; gum or granular contents in 3,806 ; average length 1,420μ.

Tracheids. A few present next to vessels, with distinct bordered pits.

EXPLANATION OF PLATES

Plate XLV

Fig. 1. Transverse section of wood of *Artocarpus integra* × 10.
Fig. 2. Transverse section of wood of *Chukrasia velutina* × 10.

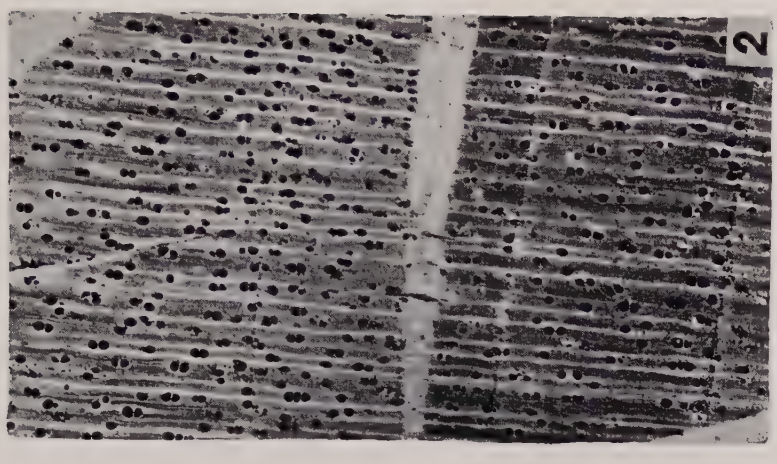
Plate XLVI

Fig. 1. Transverse section of wood of *Melia composita* × 10
Fig. 2. Transverse section of wood of *Azadirachta indica* × 10

Plate XLVII

Fig. 1. Transverse section of wood of *Berrya cordifolia* × 10.
Fig. 2. Transverse section of wood of *Pityranthe verrucosa* × 10.
Fig. 3. Transverse section of wood of *Madhuca longifolia* × 10.

(Received for publication 25th August, 1930.)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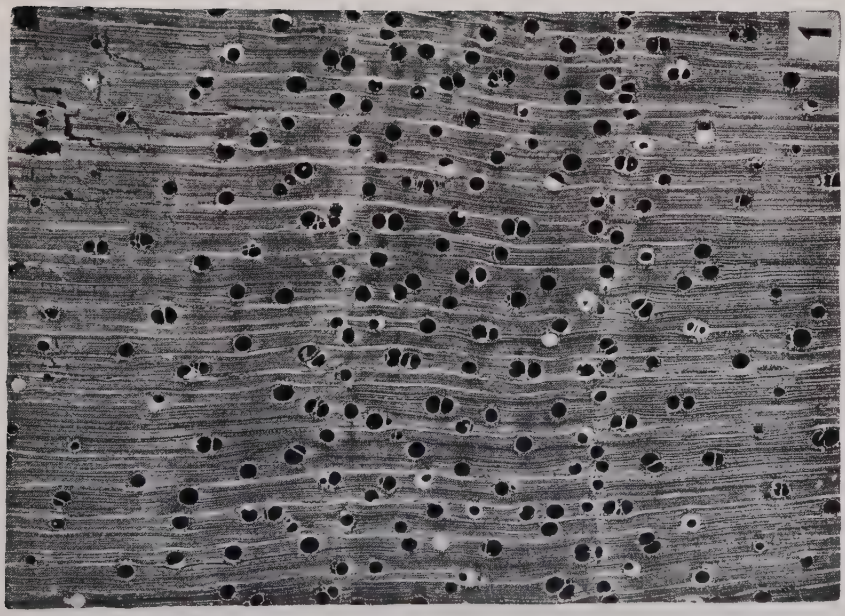
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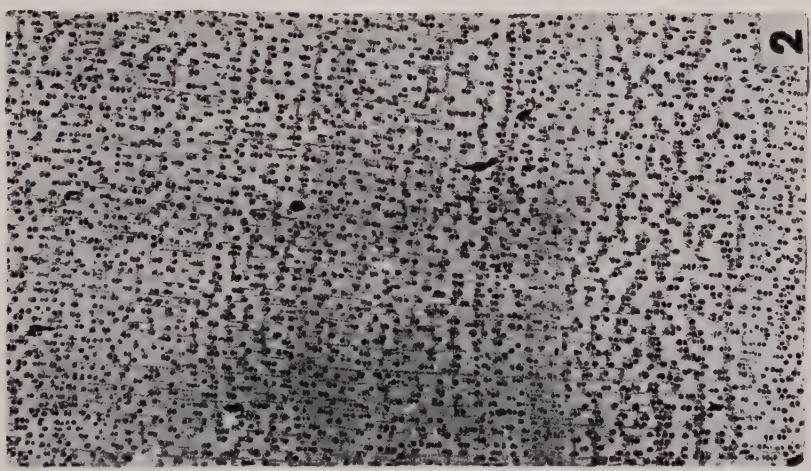
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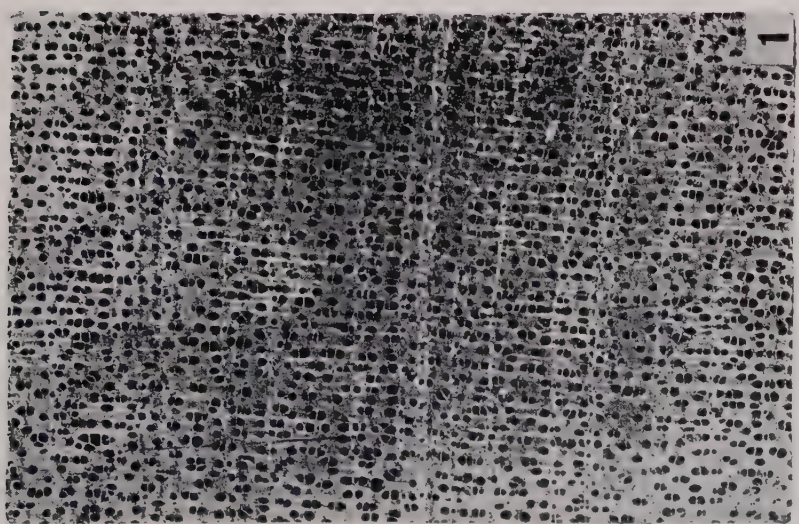
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Sclerotial Diseases of Rice in Ceylon
1. Rhizoctonia Solani Kühn

BY

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AND

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WITH ONE PLATE

INTRODUCTION

In the course of investigation of diseases of paddy in Ceylon carried out during recent years, several sclerotial fungi have been found associated with conditions of disease. It is proposed to publish the results of studies of these fungi and of their pathogenicity in a series of papers of which this is the first.

Rhizoctonia Solani Kühn is the imperfect stage of *Corticium Solani* (Prill. & Delac.) Bourd. and Galz.: for the sake of convenience the former name will be used throughout this paper except where reference is made directly to the perfect stage.

Rhizoctonia Solani is essentially a soil-inhabiting fungus and is found in most of the temperate and tropical regions of the world. Its range of host plants is extremely wide and Peltier (1) enumerated over one hundred and fifty species of plants known to be susceptible to attack by this fungus in America alone. In Ceylon, the fungus was first found by Petch (2) in 1918. Since its discovery it has been found to be parasitic on a number of plants in this country and has attracted particular attention as a serious disease of certain leguminous cover crops.

Palo (3) in a paper published in 1926 stated that *Rhizoctonia Solani* was reported on *Oryza sativa* in 1917 by Ocfemia in the Philippines.

In Ceylon the first record of this fungus on paddy was made in 1925 (4).

ETIOLOGY OF THE DISEASE

In November, 1925, diseased paddy plants on which the hyphae and sclerotia of *Rhizoctonia Solani* were present were received from the Experiment Station, Anuradhapura. The junior writer examined the affected fields in December of the same year, when there were two or three inches of water in the field and the paddy was about two months old from sowing. The diseased plants in the fields were discoloured at the base of the culm at about water level although in some cases the lesion was higher up the stem. In some plants the lesions were straw-coloured with a distinct brown margin, while in others the marginal zone was not present. Sclerotia of *Rhizoctonia Solani* were found on the surface of the discoloured areas and between the leaf sheaths. On pulling the plants from the mud, the greater part of the aerial portion of badly diseased plants separated from the roots, owing to a rot of the leaf bases, and an offensive odour was emitted. Diseased plants which bore no sclerotia when collected in the field produced them in abundance after being placed in a beaker of water for a few days. The fungus was not found on plants other than paddy in the immediate vicinity of the plots and there was no evidence as to the source of infection. At the time of inspection the bunds were clean and free from weeds. It was stated that the land on which the affected paddy was growing was a new clearing which bore only one *chena* crop before the paddy was sown. The land had to be levelled before sowing paddy and in the levelling two or three feet of soil was cut from the higher end and deposited at the lower end, with the result that one end of the field was more fertile than the other which consisted of subsoil. The plants at the former end had grown more vigorously than those at the other and it was on these better grown plants that the disease first appeared, spreading thence to the others.

An examination of the young diseased plants in the laboratory showed that the leaves were wilted but not markedly discoloured. Stems were apparently healthy but the outer leaf sheaths were dead. Sclerotia of the fungus were present on the surface of the dead leaf sheaths and between them. They were at first white, becoming brown or purple-brown. Superficial sclerotia were globose or pulvinate up to 4 mm. in diameter, while sclerotia which developed between the leaf sheaths were irregular in shape. Hyphae 5 to 9μ in diameter were present in abundance on the upper surface of many leaves and in the diseased

tissue. On some leaves the hyphae gave rise to short, swollen, much branched cells, similar to those forming the sporogenous mat of *Corticium Solani*.

In further specimens received from Kalupahana in July, 1927, hyphae and sclerotia were confined to the external parts of the plants. The affected plants were full grown and the fungus had killed only the outer leaf sheaths on which were produced numerous sclerotia.

The losses resulting from an attack vary with the age of the paddy. If the disease occurs while the plants are in the seedling stage the damage may be considerable. With a change of conditions either of weather or of soil moisture a large proportion of the plants may recover. On older plants the effect is not so marked, the outer leaves only being attacked. Such an attack is, however, discernible from a distance and must tend to reduce the final crop. The losses entailed are difficult to estimate.

THE FUNGUS IN CULTURE

The morphology and characteristics of the *Rhizoctonia Solani* isolated from paddy from Kalupahana and grown in culture were found to be similar to those described in a previous paper on the fungus (4). Pure cultures were obtained by washing sclerotia first in a 0·1% aqueous solution of corrosive sublimate and then in distilled water and transferring them direct to maize-meal agar culture tubes. The aerial mycelium of the fungus adhered closely to the surface of the culture medium and sclerotia developed superficially in four or five days. The sclerotia were white at first, becoming brown and finally purple-brown. Individual sclerotia were up to 5 mm. in diameter and occasionally united to form irregular aggregations extending to 1 cm. or more in diameter. On Dox agar, sclerotia were somewhat different; they were white at first becoming brown with a white margin as shown in the photograph (Plate XLVIII, fig. 3). With age such sclerotia became flat plates, more or less circular, up to 1 cm. diameter and uniformly chocolate-brown in colour, the differentiation of the margin disappearing.

The young hyphae of the fungus were colourless and somewhat irregular, while the older hyphae were regular, yellowish brown, 8 to 12μ in diameter, with infrequent septation.

It is proposed to discuss more fully the morphology and characters of *Rhizoctonia Solani* in the final paper of this series, in which a comparative morphology of the different sclerotial fungi on rice will be considered.

INOCULATION EXPERIMENTS

The results of early inoculation experiments with *Rhizoctonia Solani* obtained from paddy were published by Gadd and the junior writer in 1928 (4). It was shown that the strain of *Rhizoctonia Solani* isolated from paddy was capable of causing a damping-off of seedlings of a number of plants and in this respect behaved similarly to, but with differences in degree from, strains isolated from other plants. During these inoculations it was found that young seedlings of paddy when inoculated at ground level became infected at the point of inoculation ; a few seedlings died in consequence of this infection but in most only the outer leaf bases were penetrated and the plants subsequently recovered.

In the course of the present investigation numerous inoculation experiments have been carried out, the chief of which are described below. Seedlings used for stem and root inoculations were raised from seed, surface sterilised by immersion in 1% aqueous solution of corrosive sublimate, washed and finally soaked in distilled water for forty-eight hours. Unless otherwise stated stem inoculations were made by placing pieces of culture medium containing the actively-growing fungus in contact with the stem without wounding.

Seedlings

A. Stem Inoculations

Experiment 1

Two small clay pots containing paddy soil were partially sterilised by pouring boiling water over the soil. Paddy seeds were sown in the pots on May 28, 1928. After sowing, the pots were placed in a dish with water up to half the height of the pots. On June 5 the seedlings (ten in each pot) were six to nine inches high ; those in one pot were inoculated on the stems, while those in the other served as a control. Both pots were covered with a bell-jar. On June 10 light brown lesions had formed on two seedlings at the point of inoculation and the leaves of these seedlings had wilted. Hyphae from the inocula grew luxuriantly over the stems of the inoculated seedlings. On June 18 the two infected seedlings were dead and another plant had been attacked and was dying. The bell-jar was removed and, when the seedlings were examined a fortnight later, the remaining seven inoculated seedlings were growing normally, while the surface growth of the fungus was no longer apparent. The control seedlings remained healthy throughout.

Experiment 2

This experiment was similar to experiment 1, but in this the pots were not covered with a bell-jar. The seedlings were of the same age as those of experiment 1 and the inoculations were made on the same day. Six seedlings in one pot were inoculated and eight seedlings in the other acted as a control. Seven days after inoculation one seedling, which had turned brown at the point of inoculation, died. The other seedlings, both inoculated and control, remained healthy.

Experiment 3

Four Roux tubes, the lower parts of which contained a nutrient solution, were plugged and autoclaved. On May 25, 1928, the plugs were removed, two paddy seeds were inserted to germinate above the constriction of each tube and the plugs replaced. On June 5, the seedlings were three to four inches high and were inoculated about half way up the shoot. Six seedlings in three tubes were inoculated and two in one tube served as a control. A brown discoloration appeared at the point of inoculation, the stem on either side of the inoculum became greenish-brown and by June 12 all inoculated seedlings had wilted and died ; the hyphae had ascended the stem and attacked the leaves. The fungus was readily re-isolated from internal diseased tissue. The control plants remained healthy.

Experiment 4

On May 24, 1928, paddy seeds were sown in four petri-dishes on sterilised sand moistened with distilled water. On June 5 the seedlings were six to eight inches high. Inoculations were made at points just above the level of the sand and the dishes covered with a bell-jar. All the five seedlings in one dish were inoculated, three out of fourteen in the other dish and four out of five in the third dish. The fourth dish served as a control and contained five seedlings which were not inoculated. Eight days after inoculation all the inoculated seedlings were attacked and killed back. A peculiarity about the mode of attack was that the fungus did not penetrate the tissues at the point of inoculation but ascended the stem superficially, attacked the leaves and killed the seedlings from the top down to the base. Individual seedlings were examined microscopically from time to time. A seedling which had recently been killed from the top had hyphae in the internal tissue only at that region. Seedlings similarly attacked at the top but examined a few days later showed hyphae in the internal tissue lower down the stem. The fungus descended within the stem till it reached the collar but did not proceed further. Dead seedlings were examined on June 16 and no

hyphae of the fungus were traced in the roots. When diseased leaves came into contact with the leaves of a healthy plant, the latter became infected. This happened in the case of two plants in the dish which held fourteen seedlings. Although only three seedlings were inoculated five died as the result of infection by the fungus. Hyphae of the fungus grew superficially over the sand in the dishes.

B. Root Inoculations

Experiment 5

The fungus was grown in two petri-dishes on a thin layer of maize-meal agar. When the fungus was well established and had formed sclerotia, the dishes were filled with sterilised sand to the top and moistened with distilled water. Ten paddy seeds were sown in each dish on June 7, 1928. Two other petri-dishes, containing sterilised sand only, were sown with a similar number of seeds. The four dishes were placed on a table near a window and covered with a bell-jar. In three days, in the dishes containing the fungus, hyphae had grown through the sand layer, had overrun the surface of the sand and were producing sclerotia. On June 11, the seeds had germinated in all the dishes ; on June 14, hyphae were seen ascending the stems, keeping pace with the growth of the seedlings. On June 17, in one inoculated dish (A) one seedling, the shoot of which was one-half inch high, was killed back from the top. Eight other seedlings grew to a height of five to six inches and two of these were attacked through the leaves which became greenish-brown, appeared slimy and were attached with wefts of hyphae to the main stems. In the other inoculated dish (B) one seedling was killed back on June 27. Of the remaining nine seedlings, one was removed as it had fallen over ; hyphae ascended the stems of the other eight seedlings and five of these were infected through the leaves which were greenish-yellow and slimy. A sclerotium was produced on the stem of one seedling one inch above the sand. By June 25, all seedlings in dishes A and B were attacked, their leaves had turned slimy and were covered with hyphae, while a number of sclerotia had formed on the diseased tissue. All but two seedlings, one in each dish, were killed down to the base ; these two were moribund. Some of the seedlings in the control dishes also became diseased, either by their leaves coming into contact with the diseased leaves of the inoculated plants or by the hyphae reaching their leaves *via* the surface of the bell-jar. The roots of the seedlings which had been killed down to the base were carefully examined and were found to be unaffected although they were in actual contact with the fungus and growing in the culture medium.

Experiment 6

Two paddy seeds were placed to germinate at the top end of each of six plain agar slants on June 1, 1928. At the same time a small brown sclerotium of the fungus was placed at the lower end of each of three of these slants. The other three tubes served as a control. In all the tubes the seeds germinated well. In those which contained the fungus, hyphae spread from the sclerotium over the surface of the agar, attacked the stems and killed the seedlings. After death the seedlings were allowed to remain in the tubes for a few days to see whether the roots would become affected. The roots were examined on June 17 and it was found that no penetration had taken place although the fungus was present on their surfaces. The control plants remained healthy. This experiment was repeated with four other agar slants. Two seeds were put into each tube to germinate at the top end on June 2. On June 6, when the seedlings were about one inch high a single sclerotium was placed at the lower end of three tubes. In seven days hyphae had grown from the sclerotium, had ascended the seedlings and had killed them. The dead seedlings were examined on June 25 and the roots were found to be unaffected although superficial hyphae were present. The control seedlings were healthy.

Experiment 7

Six test tubes containing 1% agar up to a height of 2·5 inches were used. Four tubes were inoculated with sclerotia on July 25, 1928. After two days growing hyphae were visible and paddy soil which had been dried, crushed, sieved and sterilised was added to all the tubes so that a layer of about one inch of soil covered the agar. Two seeds were placed in each tube, a layer of soil 2 mm. thick was added over the seed and the whole was moistened with distilled water. The cotton plugs were removed from the tubes after the introduction of the soil. On July 31 hyphae had grown through the soil and along the glass and had formed sclerotia on the soil and on the glass. Hyphae were also found on the stems of the young seedlings. On August 10 straw-coloured patches with purple-brown margins were visible on the stems of some plants. A month later two seedlings died. These were carefully examined; hyphae were found to be present inside the dead tissue of the shoot but not in the roots. On October 9 the remaining seedlings were examined. Another seedling was found to be dead and hyphae were present in the dead tissue, but here again the fungus had failed to penetrate the roots. The five remaining seedlings were alive although hyphae and sclerotia were growing on the dead outer leaf sheaths. The roots of these seed-

lings were not infected, although they had been in contact with the fungus for some time. The four control seedlings were healthy.

Older Plants

Experiment 1

Paddy seed (*Maha wi*) was sown in kerosene tins on August 8, 1927. The seedlings were transplanted into nearly-cylindrical glazed clay pots twelve inches high and twelve inches in diameter on August 28, 1927. Inoculations were made on September 14, *i.e.*, thirty seven days after sowing. Four pots were used ; each pot held eleven plants. Two pots were kept flooded with about two inches of water above soil level ; in the other two the soil was kept saturated. One pot of each was inoculated by mixing culture medium containing mycelium and sclerotia of the fungus with distilled water and spreading it over the surface of the water and soil respectively. Heavy rain washed away most of the inoculum and fresh inoculum was introduced on September 23. Leaves of dadap (*Erythrina lithosperma*) were cut into shreds and spread over the water and soil before the inoculation to prevent further washing away of the inoculum by rain. Straw-coloured patches of dead tissue, surrounded by a purple-brown margin, were observed in the outer leaf sheaths of some of the plants in the inoculated pots on October 4. At this time the spots were restricted to the outermost leaf sheaths, but by October 23 one plant had been killed and the original shoot of a second plant had died back. The latter plant, however, produced later a tiller which was healthy. When the plants were examined in February, 1928, nine of them were alive, together with the tiller referred to above. In six plants, including the two dead ones, lesions had been formed on the stems at water level and had spread upwards. Hyphae of *Rhizoctonia Solani* were present on these lesions. An examination of the two dead plants revealed the presence of *Rhizoctonia* hyphae in the tissues. The roots of all the plants were healthy as were the submerged portions of the stems. By October 4 lesions similar to those recorded above had been produced at the base of the stems of some of the plants in the pot in which the fungus was placed on the surface of the soil. Sclerotia of *Rhizoctonia Solani* had been produced on the lesions and on the outer dead leaf-sheaths about one inch up the stem. Two plants had died back to ground level by October 23, but one of these produced a tiller two months later. By February, 1928, three more plants had died back to ground level and hyphae of *Rhizoctonia Solani* were found on and in the dead tissue. Lesions had been produced on the outer leaf-sheaths of two of the remaining six plants but the plants were not greatly affected. The root systems of all the

plants were healthy. One plant died in each of the control pots, but the cause of death was not apparent ; it was not due to fungus attack. Of twenty-two plants inoculated in this experiment, the fungus killed seven to ground level ; lesions were produced on six others but the injury remained local. The fact that the fungus was in actual contact with all twenty two plants for a period of over four months to produce these results indicates that it was not, under the conditions prevailing during the experiment, a virulent parasite. Further it would appear that the fungus is less likely to attack paddy plants when the latter are standing in water.

Experiment 2

Paddy seed of a four months variety were sown in pots on May 28, 1928. The plants flowered on August 20. Inoculations were made on September 7. Four pots were used ; each pot contained nine plants. The experiment was similar to the former. A few days after inoculation the leaf eating caterpillar *Lenodora vittata* Wlk. and the paddy bug *Leptocorisa varicornis* F. attacked the plants severely and vitiated the experiment. Straw-coloured patches with purple-brown margins were formed on some plants that were inoculated, but the ultimate effect of the fungus on the plants could not be gauged as deaths occurred in the control pots also as the result of defoliation by the caterpillar and the maturing of the plants.

DISCUSSION OF RESULTS

The experiments described above indicate that *Rhizoctonia Solani* is capable of infecting and killing paddy seedlings under humid conditions, such as occurred when the plants were covered with a bell-jar. It was found that the activity of the fungus was to a large extent inhibited under conditions of medium and low humidity. This confirms observations on the conditions affecting the parasitism of *Rhizoctonia Solani* made by the senior writer (5). Given atmospheric conditions approaching saturation the fungus is capable of attacking and killing, particularly from the top downwards, seedlings of paddy. Where atmospheric humidity is less infection may take place, but local lesions only are formed which affect usually only the outer leaf-sheaths. The results of experiments with older plants indicate that the fungus is capable of causing local infection under normal conditions and that mature plants will usually survive attack. These results are borne out by field observations.

In none of the experiments described above did the fungus penetrate the living roots of paddy, either of seedlings or of mature plants,

although conditions were favourable for fungus attack. It would appear from these experiments that *Rhizoctonia Solani* does not attack paddy through the roots.

VIABILITY OF SCLEROTIA

In the Philippines, Palo (3) carried out experiments with a strain of *Rhizoctonia Solani* isolated from paddy to test the viability of the sclerotia in water and at different depths in the soil. He found that sclerotia buried at depths of 5, 10, and 20 centimetres in moist soil became sponge-like in texture and lost their vitality after four to five months ; that some of the sclerotia which were placed on the surface of moist soil germinated and produced new sclerotia ; that the mother sclerotia were found to live for five months on the surface of moist soil ; that sclerotia buried at different depths in dry soil lost their vitality in six to seven months ; that sclerotia were viable for seven months on the surface of dry soil; and that sclerotia which were submerged in water lost their viability in two or three months. From his experiments Palo concluded that the viability of sclerotia in water and in soils with different moisture contents varied, the variation depending upon the moisture content of the soil and not upon the depths at which the sclerotia were buried.

In Egypt, Briton-Jones (6) failed to grow a sclerotium of *Rhizoctonia Solani* which he kept in the laboratory for four months in the summer. Even after having soaked the sclerotium for twenty four hours in water he failed to obtain growth in culture. This failure was attributed to desiccation.

In Ceylon (4) sclerotia collected from *Dolichos Hosei* in October, 1919, and stored in a corked tube in the laboratory germinated in September, 1925, when they were placed in a mixture of damp sand and dadap leaf previously sterilised. Sclerotia thus retained their vitality under dry conditions for six years and germinated when conditions became favourable.

Sclerotia isolated from paddy and grown on maize-meal were taken from a culture fifty four days old and placed on air-dried paddy soil in dishes in the laboratory. After one hundred and thirty days when transferred to maize-meal they germinated and grew in the normal way. The moisture present in the soil at the beginning of the experiment was 8·3%.

Sclerotia from a culture fifty five days old were buried at a depth of one-half inch in moist paddy soil in dishes. The moisture content of the soil at the time was 18·5% and the maximum water holding capacity

39·9%. When the sclerotia were taken out after one hundred and thirty three days and transferred to maize-meal agar they grew readily.

Sclerotia were transferred to maize-meal agar slants on September 28, 1927, and the mouths of the test tubes with the cotton plugs were immediately sealed with melted paraffin wax. On June 13, 1929, *i.e.*, after six hundred and twenty three days, the plugs were removed and sclerotia were placed on maize-meal agar. They grew readily and produced sclerotia in the normal way.

Sclerotia from a twenty seven day old culture were submerged three inches deep in a dish of tap water. From time to time a few sclerotia were taken out and grown on maize-meal agar. Sclerotia taken out after seventeen, forty six, one hundred and fifty nine and two hundred and twenty four days in water germinated. Thereafter the growth of contaminants was such that development of *Rhizoctonia Solani*, if any, was masked. A week after the immersion of the sclerotia a green slimy growth, which was an alga of the *Chlorella* type, developed in the water ; this alga is found in paddy fields. The life of the fungus was possibly prolonged by the oxygen liberated by the alga.

Sclerotia from a culture two months old were placed on air-dried paddy soil in dishes and exposed to the sun for a limited number of hours during successive days. The temperature in the sun was registered by a solar radiation thermometer with a black bulb *in vacuo*. Exposures in direct sunlight were usually for six hours each day and occasionally for three hours. The temperature was taken every hour. From time to time sclerotia were taken out and transferred to maize-meal agar culture tubes to ascertain whether they were viable. It was found that sclerotia exposed to the sun for two hundred and four hours during a period of thirty eight days would not germinate. The sun temperature during this period varied from 35°C to 69·5°C with a mean of 56·6°C. Sclerotia began to lose their viability after exposure for one hundred and eighty three hours during a period of thirty four days.

CONTROL

The experiments on the viability of sclerotia of *Rhizoctonia Solani* described in the foregoing section were undertaken to determine whether any natural condition could be utilised in controlling the disease. The results indicate that use could not be made of dry conditions in this country since sclerotia of the fungus have been shown to be capable of living for six years under dry conditions. Similarly, temporary flooding would have little or no effect on the subsequent germination of sclerotia. It has been found that prolonged exposure in direct sunlight has the effect of killing sclerotia, but under normal field conditions it would

rarely be possible to make use of this in an endeavour to control the disease. The very extensive range of host plants which have been shown to be susceptible to attack by *Rhizoctonia Solani* constitutes an obvious reason for the rejection of a scheme of crop rotation as a method of overcoming infection.

It would appear, therefore, that some direct method of treating infected soil must be adopted. Affected areas should be marked out while the crop is standing. The plants in such areas, together with a narrow belt of surrounding apparently healthy plants, should not be harvested owing to the danger of transporting sclerotia on the straw of infected plants. The diseased crop should be burned on the land, together with sufficient vegetable refuse to ensure a thorough heating of the surface soil.

SUMMARY

1. The paper is the first of a series on the sclerotial diseases of rice.

2. The occurrence is noted of *Rhizoctonia Solani* Kühn (*Corticium Solani* (Prill. and Delac.) Bourd. and Galz.) on paddy in Ceylon. Notes are given on the etiology of the disease.

3. The characteristics of the fungus on pure culture are described briefly.

4. The fungus is parasitic on paddy seedlings, especially under conditions of high atmospheric humidity. On older plants the damage caused by the fungus is less than on seedlings but is still appreciable.

5. The results are given of experiments on the viability of sclerotia under dry and wet conditions and after exposure to direct sunlight.

6. Methods of control of the disease are discussed.

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EXPLANATION OF PLATE XLVIII

Fig. 1. *Rhizoctonia Solani* on paddy. Nat. size.
Fig. 2. Pure culture of *Rh. Solani* from paddy on maize-meal agar. Nat. size.
Fig. 3. Pure culture of *Rh. Solani* from paddy on Dox agar. Nat. size.
Fig. 4. Section of sclerotium of *Rh. Solani* from paddy. × 34.
Fig. 5. Part of same section. × 250 (approx.)

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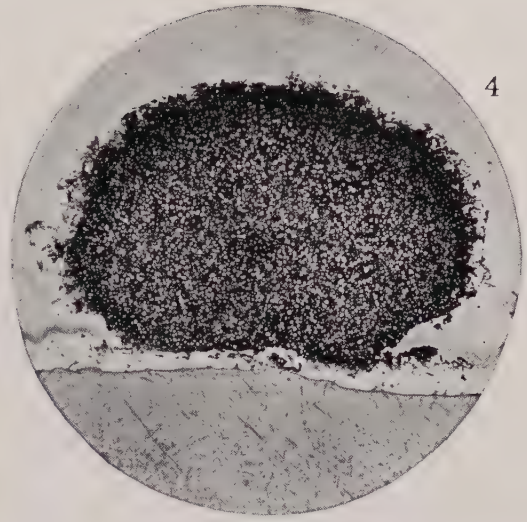
1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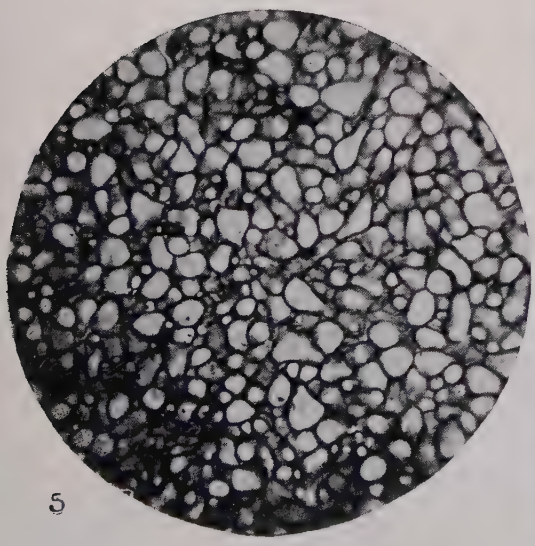
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Notes on Ceylon Diatoms. 2

BY

B. W. Skvortzow, of Harbin, China

WITH TWO PLATES

Among different gatherings of Diatoms collected by Mr. A. H. G. Alston, Systematic Botanist of the Department of Agriculture, Peradeniya, Ceylon, I have examined a sample collected by him on the 16th of August, 1926, near the sea shore at Gintota from the twigs of *Ceramium clavulatum*.

Having studied the various forms which it contains and determined the species, I give in the present note a list of 42 forms, accompanied by a few remarks concerning several of them, and by the description of some new species and varieties.

Podosira Montagnei Kütz.

V. Heurck, Synopsis. pl. 84, figs. 9—12.

Valve brown, dotted, 0·025 to 0·027 mm. in diameter. Geographic distribution : North sea, Kaspian sea, Mediterranean sea, Japan sea.

Podosira stelliger (Bail.) Mann. (Plate XLIX, fig. 9).

V. Heurck, Synopsis. pl. 84, figs. 1, 2.

Diameter of the valve 0·093 to 0·1 mm. Striae 17 in 0·01 mm. Geographic distribution : Pacific and Atlantic oceans, Philippine Islands, Japan sea.

Hyalodiscus subtilis Bailey.

Peragallo, Diatom. Mar. France. pl. 119, fig. 7.

Diameter of the valve 0·051 to 0·063 mm. Geographic distribution : Atlantic and Pacific oceans.

Coscinodiscus oculus-iridis Ehrenb.

A. Schmidt, Atlas Diatom. pl. 63, figs. 6, 7, 9.

Diameter of the valve 0·153 to 0·185 mm.Markings 3—4 in 0·01 mm. Geographic distribution : Cosmopolitan diatom, known from Japan, China seas, Java, Philippine Islands, Ceylon.

See Notes on Ceylon Diatoms 1. in *Annals of the Royal Botanic Gardens, Peradeniya*. Vol. XI, Part 3, Jan., 1930, pp. 251-260, pl. XXXII-XXXIV.

Coscinodiscus marginatus Ehrenb.

A. Schmidt, Atlas Diatom. pl. 62, figs. 1—5, 7, 9, 11, 12.

Diameter of the valve 0·068 to 0·078 mm. Markings 2—3 in 0·01 mm. Geographic distribution : Atlantic and Pacific oceans.

Coscinodiscus excentricus Ehrenb.

A. Schmidt, Atlas Diatom. pl. 58, figs. 46—49.

Diameter of the valve 0·035 mm. Markings 4—5 in 0·01 mm. Geographic distribution: Atlantic and Pacific oceans, Singapore, Philippine Islands, Japan sea.

Coscinodiscus concavus Greg. (Plate XLIX, fig. 6).

A. Schmidt, Atlas Diatom. pl. 62, fig. 8.

Diameter of the valve 0·037 mm. Markings $3\frac{1}{2}$—4 in 0·01 mm. Geographic distribution : North sea, India, Philippine Islands, Balearic Islands.

Actinocyclus Ehrenbergi Ralfs var. **Ralfsii** (W. Sm.) Hustedt.

Hustedt, Kieselalgen. Lief. 3, p. 528, fig. 299.

Diameter of the valve 0·157 to 0·185 mm. Markings 6—7 in 0·01 mm. Geographic distribution : A cosmopolitan diatom.

Aulacodiscus orientalis Grev. (Plate XLIX, fig. 8).

A. Schmidt, Atlas Diatom. pl. 34, figs. 1—3.

Diameter of the valve 0·127 to 0·133 mm. Geographic distribution : Philippine Islands, Celebes, Sandwich Islands.

Actinoptychus splendens (Shadb.) Ralfs.

V. Heurck, Synopsis. pl. 191, figs. 1, 2, 4.

Diameter of the valve 0·095 to 0·1 mm. Geographic distribution : Atlantic and Pacific oceans, Philippine Islands.

Biddulphia alternans Bailey. (Plate XLIX, fig. 3).

A. Schmidt, Atlas Diatom. pl. 78, figs. 9—18.

L. 0·018 to 0·023 ; B. 0·028 to 0·032 mm. Puncta 6 in 0·01 mm. Geographic distribution : Mediterranean sea, Campeachy Bay, Peru, Guano.

Biddulphia Roperiana Grev.

V. Heurck, Synopsis. pl. 99, figs. 4—6.

L. 0·04 ; B. 0·03 mm. Geographic distribution : Atlantic and Pacific oceans, Japan sea, Philippine Islands.

Biddulphia favus (Ehrenb.) V. Heurck.

A. Schmidt, Atlas Diatom. pl. 82, figs. 13,14.

Valve triangular 0·07 mm. in diameter. Geographic distribution : Atlantic and Pacific oceans, Japan sea.

Biddulphia juncta (A. Schmidt) Mann. (Plate XLIX, figs. 1, 5).

A. Schmidt, Atlas Diatom. pl. 98, figs. 1—3.

Valve quadrangular. B. 0·068 to 0·075 mm. Puncta distinct 5 to 6 in 0·01 mm. Geographic distribution: Madagascar, Seychelles.

Biddulphia reticulata Roper. (Plate XLIX, figs. 2, 4).

A. Schmidt, Atlas Diatom. pl. 121, figs. 11—15.

L. 0·025 to 0·064; B. 0·015 to 0·042 mm. Geographic distribution: Celebes, Sandwich Islands, Java, Japan sea, Philippine Islands.

Biddulphia pulchella Gray. (Plate XLIX, fig. 7).

A. Schmidt, Atlas Diatom. pl. 118, figs. 26—33.

L. 0·07 to 0·09; B. 0·039 to 0·051 mm. Geographic distribution: A cosmopolitan diatom.

Isthmia enervis Ehrenb.

V. Heurck, Synopsis. pl. 96, figs. 1—2.

L. 0·12 to 0·15; B. 0·059 to 0·073 mm. Geographic distribution: Pacific ocean, North sea, Mediterranean sea.

Synedra affinis Kütz. var. **parva** Grun.

V. Heurck, Synopsis. pl. 41, fig. 22.

L. 0·032; B. 0·0042 mm. Striae 20 in 0·01 mm. Geographic distribution: North sea, Mediterranean sea, Japan sea.

Grammatophora angulosa Ehrenb. var. **uncina** Grun. (Plate L, fig. 8).

V. Heurck, Synopsis. pl. 53, fig. 6; Leuduger-Fortmorel, Diatom. Ceylan. p. 55, pl. 5, fig. 60.

L. 0·025; B. 0·015 mm. Striae 15 in 0·01 mm. Geographic distribution: North America, Black sea, Adriatic, Japan sea, Ceylon.

Grammatophora marina (Lyngb.) Kütz. var. **undulata** Ehrenb. (Plate L, fig. 13).

V. Heurck, Synopsis. pl. 53 Bis. fig. 17.

L. 0·025 to 0·051; B. 0·017 mm. Striae 6 to 7 in 0·01 mm. Geographic distribution: Adriatic, Pacific oceans, Philippine Islands.

Grammatophora maxima Grun. (Plate L, fig. 10).

V. Heurck, Synopsis. pl. 53, figs. 12,13.

L. 0·076; B. 0·02 mm. Geographic distribution: Gallapagos Islands, Adriatic.

Rhabdonema adriaticum Kütz.

A. Schmidt, Atlas Diatom. pl. 217, figs. 17—29.

L. 0·068 to 0·085 mm. Geographic distribution: Atlantic, Mediterranean sea, Red sea, Australia.

Rhabdonema mirificum W. Smith. (Plate XLIX, fig. 10).

A. Schmidt, Atlas Diatom. pl. 217, figs. 1—3.

L. 0·17 to 0·203 mm. Geographic distribution: Java, Philippine Islands, Japan sea.

Cocconeis scutellum Ehrenb. var. **japonica** Skvortzow.

Marine Diatom. Dairen, p. 421, pl. 1, fig. 8.

Valve elliptical with rounded ends. L. 0·0204 ; B. 0·012 mm. Puncta 9 in 0·01 mm. Geographic distribution : Japan and Yellow seas.

Cocconeis composita A. Sm. var. **recta** var. nov. (Plate L, fig. 1).

Valve elliptical. L. 0·056 ; B. 0·047 mm. Upper valve with broadly linear axial area, on both sides of which are two arcuate furrows. Lower valve with a straight median line, not reaching to the margin. Axial area narrow, central area small. Striae 9 in 0·01 mm. *Cocconeis composita* A. Sm. in Atlas Diatom. pl. 196, figs. 4,5, is known from Yokohama and has a sigmoid median line.

Cocconeis heteroidea Hantzsch. (Plate L, fig. 2).

A. Schmidt, Atlas Diatom. pl. 196, figs. 2, 31—34.

Valve elliptical. L. 0·024 to 0·056 ; B. 0·015 to 0·047 mm. Geographic distribution : Seychelles, Madagascar, Mauritius, Singapore, Japan sea, China, Sandwich Islands, Samoa, Philippine Islands.

Cocconeis heteroidea Hantzsch. var. **curvirotunda** Temp. et. Brun (Plate L, fig. 9).

A. Schmidt, Atlas Diatom. pl. 195, figs. 10—17.

Valve broad elliptical. L. 0·039 ; B. 0·029 mm. Geographic distribution : Japan—fossil.

Cocconeis heteroidea Hantzsch. var. **simplex** var. nov. (Plate L, fig. 7).

Valve minute, broadly elliptical. L. 0·013 to 0·02 ; B. 0·008 to 0·012 mm.

Upper valve with sigmoid, oblique axilar area without furrows. Striae 27 in 0·01 mm. Lower valve with sigmoid median line. Axial area narrow.

Navicula peregrina Ehrenb. forma.

A. Schmidt, Atlas Diatom. pl. 47, figs. 57—60.

Valve lanceolate with obtuse ends. L. 0·08 ; B. 0·012 mm. Striae in the middle 7 in 0·01 mm. Geographic distribution : Brackish waters. Sea of Kara, Baltic, North sea, Adriatic, Atlantic coasts of America, Cape Wankarema, Japan, Batavia.

Navicula (Schizonema) ramosissima Ag. forma **genuina** Cleve.

V. Heurck, Synopsis. p. 110, pl. 15, figs. 4, 5.

Valve linear-lanceolate. L. 0·037; B. 0·0085 mm. Striae 15 in 0·01 mm., parallel. Geographic distribution : North, Mediterranean and Japan seas.

Navicula (Schizonema) ceylanica sp. nov. (Plate L, fig. 6).

Valve lanceolate, obtuse. L. 0·034 ; B. 0·0084 mm. Axial and central areas indistinct. Striae 15 to 17 in 0·01 mm., parallel. A form intermediate between *N. mollis* and *N. ramosissima*.

Diploneis fusca Greg. var. **delicata** A. Sm.

Valve elliptical. L. 0·035 ; B. 0·017 mm. Striae 11 in 0·01 mm. Geographic distribution : North sea, Adriatic, Sumatra, Philippine Islands, Hungary—fossil.

Diploneis major Cleve.

A. Schmidt, Atlas Diatom. pl. 7, figs. 18,19, 21,22.

Valve robust. L. 0·102 to 0·148 ; B. 0·07 to 0·08 mm. Striae 3 to 5 in 0·01 mm. Geographic distribution : North sea, Sumatra, China, Japan, Australia, California—fossil.

Trachyneis velata A. Schmidt.

A. Schmidt, Atlas Diatom. pl. 48. figs. 33—35, 36,37 (no name).

Valve lanceolate with obtuse ends. L. 0·119 to 0·2 ; B. 0·026 to 0·03 mm. Striae 17 in 0·01 mm. Geographic distribution : Cape of Good Hope, Madagascar, Mauritius, Ceylon, Sumatra, Java, China, Japan, Sandwich Islands, Cape Horn.

Orthoneis splendida Greg. (Plate L, fig. 11).

V. Heurck, Synopsis. pl. 28, figs. 1, 2.

Valve elliptical. L. 0·074 to 0·08 ; B. 0·064 to 0·07 mm. Striae 7 to 8 in 0·01 mm. Geographic distribution: Scotland, Bohusland, Mediterranean sea, Adriatic, Red sea, Seychelles, Madagascar, Sumatra, China, Japan, Galapagos Islands, Honduras, West Indies and fossil in Hungary, California and Oamaru.

Gyrosigma attenuatum Kütz.

Peragallo, Monogr. *Pleurosigma*. pl. 7, figs. 4 to 7 and 9.

Valve lanceolate, sigmoid L. 0·127 to 0·175 ; B. 0·024 to 0·027 mm. Geographic distribution : Fresh and brackish waters. Sweden, Finland, England, Saxony, Belgium, France, Baltic, North sea, Caspian sea.

Amphora angusta (Greg.) Cleve var. **ceylanica** var nov. (Plate L, fig. 5).

Valve narrow, semi-lanceolate, acute, with rounded ends. L. 0·057 ; B. 0·0085 mm. Striae 18 to 20 in 0·01 mm.

Amphora bigibba Grun. (Plate L, fig, 12).

A. Schmidt, Atlas Diatom. pl. 25, figs. 66, 67, 69 to 77.

L. 0·017; B. 0·0068 mm. Geographic distribution : Balearic Islands, Adriatic, Japan sea, Chile, Galapagos Islands, West Indies, Campeachy Bay.

Nitschia Lorenziana Grun. var. **subtilis** Grun. (Plate L, fig. 14).

A. Schmidt, Atlas Diatom. pl. 335, figs. 6,7.

L. 0·17; B. 0·0085 mm. Geographic distribution : North sea, Mediterranean sea.

Nitschia panduriformis Greg. var. **delicatula** Grun.

V. Heurck, Synopsis, pl. 58, fig. 5.

L. 0·034 ; B. 0·012 mm. Geographic distribution : North sea, Mediterranean sea.

Surirella fastuosa Ehrenb.

A. Schmidt, Atlas Diatom. pl. 5, figs. 7, 8, 11.

L. 0·039 to 0·055 ; B. 0·03 to 0·04 mm. Geographic distribution : A cosmopolitan diatom.

Campylodiscus Kinkeri A. Schmidt. (Plate L, figs 3, 4).

A. Schmidt, Atlas Diatom. pl. 207, fig. 16.

Diameter of the valve 0·039 to 0·044 mm. Costae 5 in 0·01 mm. Geographic distribution : Malay Archipelago, Philippine Islands.

EXPLANATION OF PLATES

Plate XLIX.

Fig. 1. *Biddulphia juncta* (A. Schmidt) Mann.
„ 2. *B. reticulata* Roper.
„ 3. *B. alternans* Bailey.
„ 4. *B. reticulata* Roper.
„ 5. *B. juncta* (A. Schmidt) Mann.
„ 6. *Coscinodiscus concavus* Greg.
„ 7. *Biddulphia pulchella* Gray.
„ 8. *Aulacodiscus orientalis* Grev.
„ 9. *Podosira stelliger* (Bail.) Mann.
„ 10. *Rhabdonema mirificum* W. Smith.

Plate L.

Fig. 1. *Cocconeis composita* A. Sm. var. *recta*. var nov.
„ 2. *C. heteroidea* Hantzsch.
Figs. 3-4. *Campylodiscus Kinkeri* A. Schmidt.
Fig. 5. *Amphora angulosa* (Greg.) Cleve var. *ceylanica* var. nov.
„ 6. *Navicula* (*Schizonema*) *ceylanica* sp. nov.
„ 7. *Cocconeis heteroidea* Hantzsch. var. *simplex* var. nov.
„ 8. *Grammatophora angulosa* Ehrenb. var. *uncina* Grun.
„ 9. *Cocconeis heteroidea* Hantzsch. var. *curvirotunda* Temp. et Brun.
„ 10. *Grammatophora maxima* Grun.
„ 11. *Orthoneis splendida* Greg.
„ 12. *Amphora bigibba* Grun.
„ 13. *Grammatophora marina* (Lyngb.) Kütz. var. *undulata* Ehrenb
„ 14. *Nitschia Lorenziana* Grun. var. *subtilis* Grun.

(Received for publication 5th March, 1931.)

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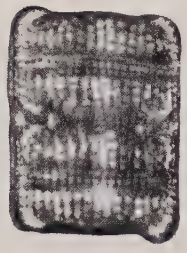

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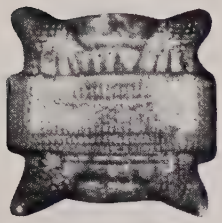

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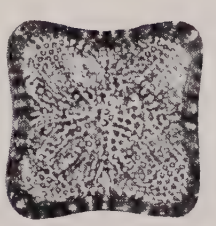

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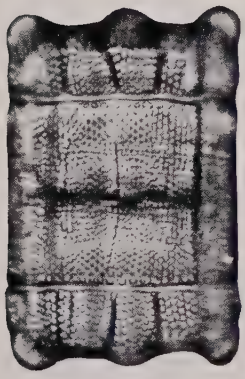

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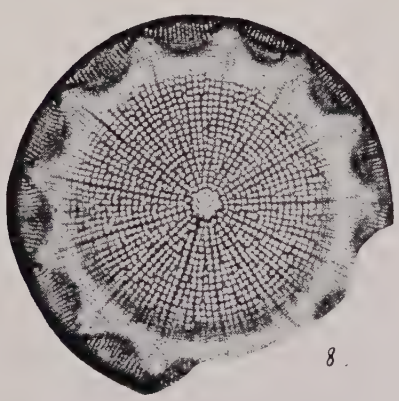

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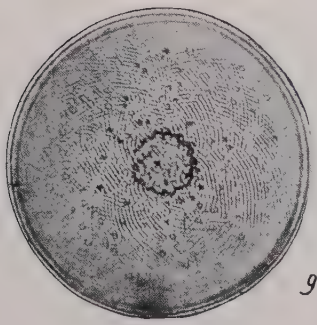

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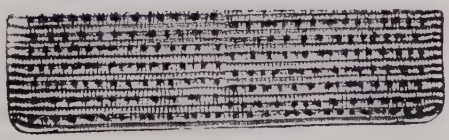

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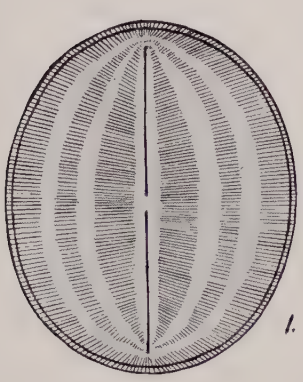
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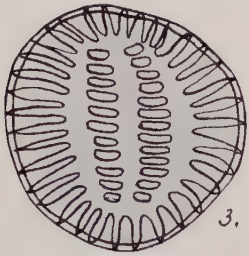
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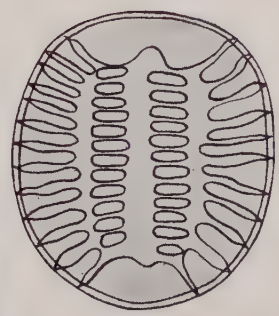
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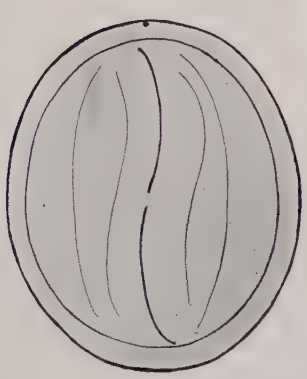
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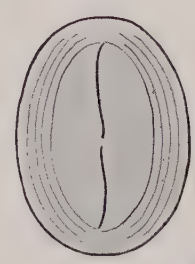
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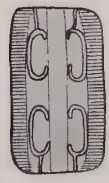
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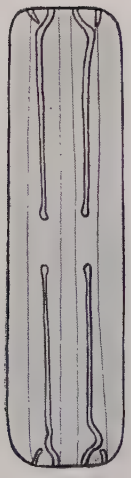
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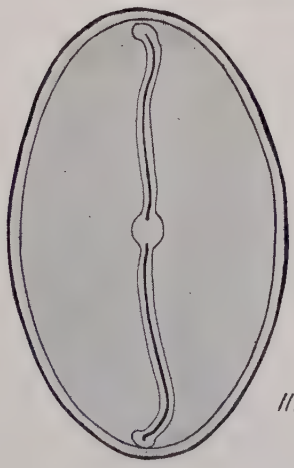
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13.

A Preliminary Study of Natural Cross-pollination of Rice in Ceylon

BY

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Natural cross-pollination in rice has been investigated in most rice-growing countries. The amount of crossing has been found to vary largely, due probably both to climatic and varietal differences, and the range is from practically no cross-pollination in California and Hawaii to 23% in Java. The literature on this subject has lately been reviewed by Jones,[1] whose very useful bibliography should be consulted.

A study of the blooming of rice in Ceylon had shown that crossing would probably be rare, but in 1929 it was considered advisable to get definite information on this. Accordingly investigations were started at Peradeniya (1,500 ft. above sea level ; average rainfall 89″) and at Anuradhapura (295 ft. above sea level, in the northern dry zone ; average rainfall 55″).

DESCRIPTION OF THE INVESTIGATIONS

These were commenced in the *maha* season of 1929-30 and the rices used were the 6-6½ months' pedigree selections I.17 and P.10. I.17 has a red testa colour and P.10 a white. Red colour is dominant to white. To ensure optimum conditions for cross-pollination a line of P.10 plants was transplanted between two lines of I.17. The three lines formed a plot. There were three plots in which the I.17 plants were respectively (1) ten days older (3) ten days younger than the P.10 plants and (2) the same age as P.10. It was considered that by using I.17 plants of different ages there would be one plot in which the plants of the two selections would flower at the same time. This happened in plot 3 and the P.10 plants in this plot were harvested and threshed. The resulting seed was sown in a nursery for the 1930-31 season and the seedlings planted out 6″ apart, one plant per hill.

1. Jones, J. W. Review of the literature on pollination, hour of blooming and natural crossing in rice.
Office of Cereal Crops and Diseases, Bureau of Plant Industry, U. S. Department of Agriculture, 1929.

At Anuradhapura the same method was adopted with four-month selections but here there were two series each with three plots, as at Peradeniya, where the ages of the outside rows of plants varied. In series (a) Hp.9 a light-glumed, awnless selection was planted between lines of Hf.23 a dark-glumed, awned selection. Awning is dominant to awnlessness and dark glumes usually dominant to light. As will be seen later there was not complete dominance, but for the purposes of this study any Hf.9 progeny showing either of the characters of Hp.23 has been taken as being a hybrid. In series (b) the same female parent Hp.9 was used but with a different male parent, Hn. 15. Hn. 15 is a dark-glumed, awnless paddy slightly longer aged than Hf. 9. The plants in plot (1) in series (a) and plot (3) in series (b) flowered at the same time and the inner lines of Hf. 9 plants of these two plots were harvested and threshed separately. The resulting seed was sown in two nurseries for the 1930-31 *maha* season and the seedlings were transplanted in hills 12″ apart, one plant per hill.

STATEMENT AND DISCUSSION OF RESULTS

At the end of the *maha* 1930-31 season the plants of the three series were examined individually with the following results:—

Peradeniya, Series (a)

Total number of plants	2,984
Number of crosses	20
Percentage of crossing	0·67

The crosses were identified by their red testas; the remaining plants had white testas.

Anuradhapura, Series (a), Hp.23 and Hf.9

Total number of plants transplanted ..	4,130
Number of crosses	14
Percentage of crossing	0·34

The fourteen crosses differed from the female parent as follows:—

3 plants had awns and dark glumes.
4 plants had awns and light glumes.
5 plants had short awns and light glumes.
2 plants had dark glumes and indefinite awns.

Anuradhapura, Series (b), Hn.15 and Hf.9

Total number of plants transplanted	4,130
Number of crosses	16
Percentage of crosses	0·39

The sixteen crosses differed from the female parent as follows :—

12 plants had dark glumes and a longer age.
4 plants had dark glumes but were the same age.

The segregation of the different factors in the two series at Anuradhapura is interesting and requires further study. The number of plants which matured in each plot at Anuradhapura was not counted ; it has been assumed that all the plants transplanted reached maturity. It is very likely that there were some casualties in the seedling stage, but it is thought that the percentages will be but slightly affected. It will be seen that the use of different male parents at Anuradhapura in the two series has had little effect on the results. There is no *a priori* reason why the two pollens should behave differently and the close similarity of the results is some evidence of their accuracy.

The experiment was not designed to show how many of the original plants bore one or more flowers which were cross-pollinated. The figure of 0·67% represents the total amount of crossing. It is, of course, possible but unlikely that all the crossed plants were produced by one mother plant, and further investigations should be carried out in such a way as to furnish information on this point.

In this preliminary study only two (although widely different) varieties have been used as female parents and only for one season. Before a categorical pronouncement can be made on the extent of natural crossing in rice in Ceylon further trials with other varieties over a number of years will be necessary, but even this investigation (and the fact that it was carried out at two climatically different centres enhances its value) has served to confirm the opinion that crossing is very small. From the point of view of the grower of pedigree seed the amount of crossing shown above is negligible. In the investigation the conditions for cross-pollination were as favourable as possible. In commercial seed growing the possibilities of crossing will be considerably lessened.

SUMMARY OF RESULTS

A preliminary investigation with two varieties of rice in two climatically different districts in Ceylon has shown that the amount of natural crossing varies from 0·34 to 0·67%.

Further investigations with other varieties over a number of years are necessary before a definite pronouncement on the extent of natural crossing of rice in Ceylon can be made.

ACKNOWLEDGMENT

The writer was transferred to another post before these investigations were finished. He wishes to thank his successor Mr. J. C. Haigh, Economic Botanist, who very kindly supervised the harvesting of the 1930-31 plants, examined the seed and prepared a statement of the results.

(Received for publication 23rd April, 1931.)

Sclerotial Diseases of Rice in Ceylon
2. Sclerotium Oryzae Catt.

BY

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AND

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WITH TWO PLATES

INTRODUCTION

Sclerotium Oryzae was first recorded and described as the cause of a disease of paddy in Italy by Cattaneo in 1879. In 1910 Miyake (1) recorded the fungus in Japan, where it was reported to have caused considerable damage in certain paddy fields. Shaw (2) in describing the disease as it occurred in various localities in India in 1911 and 1912 stated that " infected plants can usually be distinguished from their healthy neighbours by the phenomenon of 'tillering,' that is to say, the development of fresh green shoots from adventitious buds at the base of the infected culm. The infected culm gradually turns yellow and dies ; any grain which it bears is light and poorly developed, in fact there is usually nothing within the glumes. The most distinctive feature, indeed the easiest means of detecting infected plants in the field is the ' tillering ' from the base.....It is the loss of grain which constitutes the most serious damage due to this fungus." In 1912 Butler (3) suggested that *Sclerotium Oryzae* was one of the causes of sterility in paddy. Tisdale (4), in reporting the disease in Louisiana, stated that " In the rice fields of Crowley, La, in the spring of 1919 an abundance of small, black sclerotia was found in the tissues and on the surface of old rice plants and stubble of the previous year. The same condition was noted again in the spring of 1920, at which time the organism was obtained

in pure culture from the sclerotia. The fungus was then thought to be of an entirely saprophytic nature. On August 5, 1920, considerable lodging was noted in a field of Early Prolific rice which was being harvested near Crowley. The affected plants were more or less collapsed, and the panicles were generally poorly filled and light. Near the ground, two or three nodes from the base, the stems appeared darker, and the internode where the irrigation water stood was found to be almost completely destroyed.....In the cavity of the diseased portion of the stem and in the diseased tissues, a weft of fine, white mycelium and numerous small, spherical sclerotia could be seen.....Symptoms of the disease given by the Eastern writers are identical with the symptoms of diseased plants in Louisiana with the exception of tillering mentioned by Shaw and Butler in India. This condition does not occur in this country to any noticeable extent.....The most severe damage is caused at the time the vitality of the stem is declining and the panicles are filling. The plants are weakened and the resulting panicles are poorly filled and light."

Petch in 1913 received *Sclerotium Oryzae* on paddy (No. 3737 Herb. Perad.) from Hewessa, Pasdun Korale. The fungus has subsequently been recorded from Trincomalie, Kelaniya, Aturugiriya in the Hewagam Korale in the Colombo district, Peradeniya, Hanguranketa, Agalawatte, Balangoda, Divulgaspitiya, Kalupahana, Anuradhapura and Galle. It would appear, therefore, that the fungus occurs in most of the paddy-growing areas in Ceylon.

SYMPTOMS

Bryce (5), reporting the first appearance of the disease at Peradeniya, wrote: "*Sclerotium* disease has been recorded from various localities and caused a considerable amount of damage in some of the old paddy fields at the Peradeniya Experiment Station. The most susceptible paddy varieties were Macan Pina from Manila and Hatiel." In 1921 a field officer forwarded the following notes when reporting the disease from Hanguranketa: "Crop in ear—green but beginning to ripen ; a variable number of tillers of paddy plants were dull brown in colour—stem, leaf and ear ; the grains were partly developed, not empty as with stem borer attack ; the nodes of stems were rotten and a stem, if pulled gently, parted immediately at one of the nodes." The specimens received were all attacked by *Sclerotium Oryzae*.

Similar field symptoms were reported from Divulgaspitiya where the progress of the disease from the roots upwards was noted. The junior writer visited the area and found that a large proportion of plants in certain fields had been killed. The disease was said to have originated

at several points in one field and it appeared that infection had been carried by water to other fields. All the affected areas were in a poor state of cultivation and were excessively wet. At the time of the visit the crop of paddy was fully grown with the grain of those plants that were healthy in the " milk " stage. The disease appeared to be rapid in action, one month only elapsing after the disease was first noted before the full damage occurred. *Sclerotium Oryzae* was abundant on the dead plants.

A further outbreak, which disclosed certain points of interest, was observed in nursery plants at Peradeniya. The field in which the nurseries were situated was cultivated and manured with superphosphate at the rate of one hundred-weight per acre and with wild sunflower (*Tithonia diversifolia* A. Gray) at the rate of one and a half tons per acre. After cultivation the field was divided into four nurseries and it may be assumed therefore that soil infection with *Sclerotium Oryzae*, if that fungus was present in the soil, was uniform throughout the nurseries. Four varieties of paddy, of which three were varieties from Burma and new to Ceylon, namely, *Hmawbi* 37, *Hmawbi* 39 and *Ngasein*, and a local variety, *Hondurawela*, were sown in the four nurseries. The seedlings were attacked when they were about six inches high. Symptoms displayed by infected plants were typical ; the leaves, commencing from the outermost, turned successively yellow and then brown. Numerous sclerotia of *S. Oryzae* were found in the roots and on and in the base of the shoots. Variation in severity of attack was observed in the four nursery plots. *Hmawbi* 37 was very severely attacked and only a small proportion of the plants survived. The attack on *Hmawbi* 39 and *Ngasein* was decreasingly severe in the order named, while the local *Hondurawela* was not attacked. An attempt was made to explain the varying attack on the different varieties. It seemed possible that the seed might have been infected, but germination and growth tests in pot culture in conditions favourable for attack produced only healthy seedlings in all four varieties. As has been stated above, the whole area was cultivated as one and it would appear likely therefore that infection of the soil by the fungus was uniform throughout the plots. These considerations point to the possibility of varietal susceptibility to the disease. On the other hand, *Sclerotium Oryzae* is known to be common in Burma without causing serious disease. Conditions at the time of the outbreak were very wet, and it is possible that these wet conditions reacted on the newly-imported Burma paddies and rendered them more susceptible to the disease than the local paddy grown under similar conditions.

Specimens of older paddy attacked by *Sclerotium Oryzae* received by the Division of Mycology from time to time for investigation and

report have exhibited in some cases symptoms similar to those described by Shaw and in others symptoms as described by Tisdale. The writers have also found *Sclerotium Oryzae* growing as a saprophyte on the dead outer leaf-sheaths of healthy plants in full ear. This might have been due to the fungus infecting the plant too late to cause any appreciable difference to the health of the plant or loss in grain. In *Sclerotium Oryzae* attack on bigger plants the roots have always been found to be free from infection, sclerotia of the fungus being present in the hollow culm ; only in the case of young seedlings were the roots found to be affected. The symptoms exhibited by affected plants may be summarised thus :—

Seedlings—The outer leaves turn yellow and then brown followed in succession by the inner leaves. Sclerotia are found in the roots. Lesions caused by the fungus may be formed on the shoots, especially at water level. Sclerotia are found on and in the lower parts of diseased leaves.

Older plants—The disease can be readily detected in the field on plants which are approaching maturity by the unusual production of young shoots or tillers from the base of the stem or sometimes from nodes above the surface of the soil. The stalk gradually turns yellow and dies and any grain which it bears is light ; usually there is nothing in the ear. If a diseased stem is split, sclerotia can be seen dotted over the inner surface (Plate LI, fig. 1) ; the fungus is most commonly found at the base of the stem but may occur higher up.

THE FUNGUS

The mycelium forms a white or greyish woolly growth within the hollow stem. The hyphae are 4 to 8μ in diameter, stout, hyaline, becoming brownish, sometimes deep brown ; when a branch is given off from a main hypha the branch may be constricted at the point of origin. A branch may be produced at right angles to the parent hypha or it may emerge inclined towards the direction of growth and lie parallel to it.

Sclerotia are developed from the mycelium on the inner surface of the hollow stem (Plate LI, fig. 1). They are sphaeroidal bodies, smooth, black and shiny and from 195 to 342μ in diameter. When they are deeply embedded in the tissues they have a diameter of about 100μ.

Pure cultures are easily obtained from sclerotia picked from diseased material by first rinsing them in 0·1% corrosive sublimate solution, washing in sterile water and transferring to culture medium plates and slants. Direct cultures may also be made by transferring loose greyish hyphae found in the diseased hollow stalks to culture tubes. The fungus

was grown on maize-meal agar, lima bean agar and glucose agar and the notes on its behaviour on the different media are given below.

Maize-meal agar—Four days after inoculation a luxuriant growth of white fluffy hyphae develops from the introduced sclerotium and spreads over the surface of the culture medium. A day or two later, the older hyphae round the sclerotium become greenish-brown as do the hyphae at the edge of the medium where it comes into contact with the glass ; later the older hyphae turn smoky olive-brown and finally slate gray in colour. About eight days after inoculation minute white sclerotia, which later turn grey and finally black, are formed on the hyphae on the surface of the medium and also partly embedded in the medium. With the growth of the fungus the colour of the culture medium becomes pale amber, then coral-pink and finally clay-brown. Where the medium meets the glass at the sides hyphal growth is at first greenish brown, then dark brown and finally black. In old cultures a pseudoparenchymatous stroma, greyish-black in colour, is formed on the culture medium in which large numbers of sclerotia are embedded. Sclerotia are also produced on the hyphae which ascend the glass from the edges of the medium.

Glucose agar—About four days after inoculation a loose white fluffy growth develops over the surface of the medium ; where the culture medium meets the glass the hyphae are greenish-brown. With advance in growth the colour of the medium changes to pale crimson and later to crimson red or maroon brown. A white felt of mycelium develops on the surface of the medium and about ten days after inoculation a sparse production of small slate-grey sclerotia takes place on this felt and on the hyphae which have ascended the sides of the glass. With age the mycelium forming the felt on the medium becomes smoky white in colour, and a dark olive-brown margin develops at the edges of the medium. In old cultures the mycelial felt on the medium becomes slightly wrinkled, the colour of the medium changes to amber-grey and the sclerotia turn black.

Lima bean agar—Growth in this medium is similar to that on glucose agar but the colouring of the medium is not so marked. A slight orange-red colour develops at the apex of the medium in tube cultures. Sclerotia are produced scantily from the hyphae on the medium and may also be formed embedded in the culture medium.

Dox agar—Mycelial growth is submerged and on the third day after inoculation the medium develops a pinkish tinge which gradually develops into a coral pink colour. With age the colour of the medium changes to pale buff. A fortnight after inoculation some of the sub-

merged hyphae turn greenish-brown. In petri-dishes these greenish-brown hyphae are not produced until the culture is three weeks old. In tube cultures two months old the colour of the medium is buffy-olive and the hyphal growth almost black. No sclerotia are produced.

Of the four media, maize-meal agar appears to be the most suitable for the abundant production of sclerotia. In all the media tested varying amounts of colour develop; the colour is due to the infusion of a pigment into the medium.

The mycelium in culture does not differ from that in nature. The hyphae are hyaline, septate, olive-brown to pale yellow-brown in colour, 4 to 8μ in diameter and profusely branched. Branch hyphae are often constricted at the point of origin at which point a transverse septum may be formed. On glucose agar the hyphae at the edges of the medium possess irregularly swollen cells nearly 12μ broad (Plate LII, fig. 1). On Dox agar the greenish-brown hyphae consist of chains of pale olive-brown chlamydospore-like cells (Plate LII, figs. 6 and 7). Individual cells vary in diameter from 7 to 11μ. On glucose agar similar cells are produced but to a lesser degree.

Young sclerotia develop on the surface of the media and on the hyphae on the glass in the tubes. They arise from a network of hyphae which branch and interlace to form small grey bodies which later become black. Mature sclerotia are spherical or almost spherical, black, smooth and shiny. Measurements were made of two hundred sclerotia taken from points about one-half inch from the point of inoculation in a maize-meal agar culture fourteen days old. The diameters varied from 175 to 580μ. They were grouped into classes of 50μ as shown in the table below; the mean diameter was found to be $374{\cdot}5 \pm 4{\cdot}3\mu$ with a standard deviation of 92μ. Text figure 1 is a frequency curve of these observations.

Group range in μ	*Size of sclerotia in μ*	*Frequency*	
200	175—224	8	
250	225—274	24	
300	275—324	26	
350	325—374	43	Mean $374{\cdot}5 \pm 4{\cdot}3$ μ
400	375—424	48	$\sigma = 92{\cdot}0$ μ
450	425—474	28	
500	475—524	8	
550	525—574	9	
600	575—624	6	
		200	

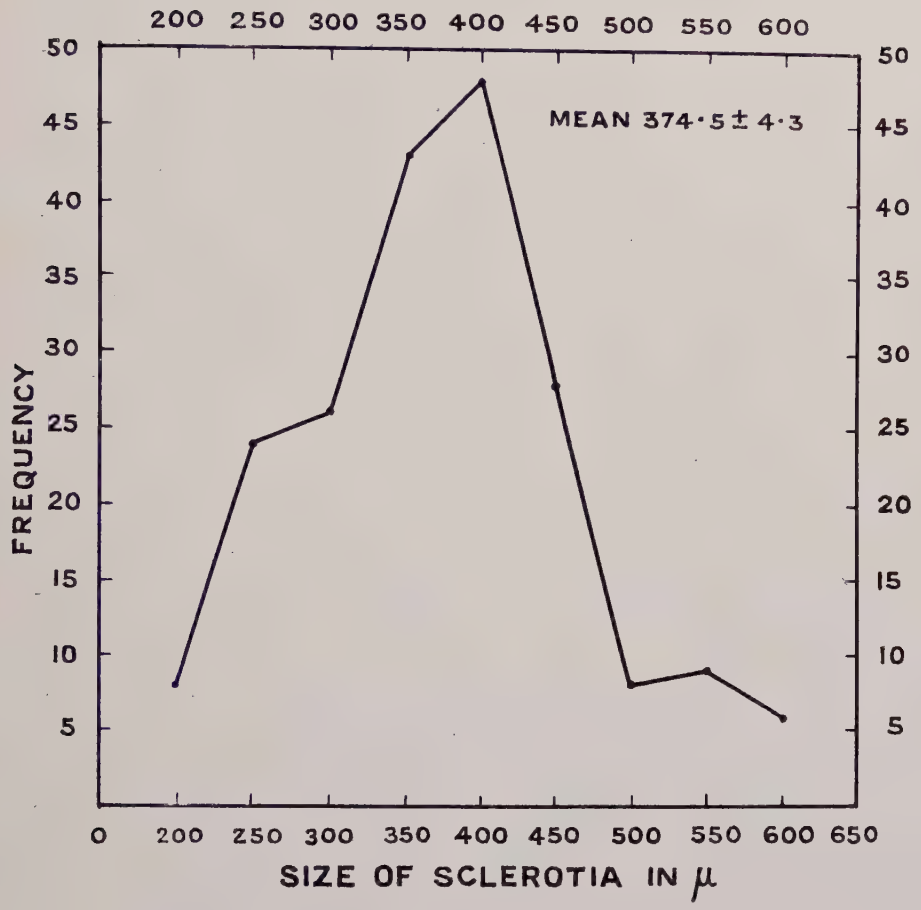

Fig. 1.—Frequency curve of sclerotial sizes

In section the sclerotium is uniformly pseudoparenchymatous, there being no differentiation into cortex and medulla, but the outside layer of cells is somewhat flattened and possesses thicker walls than the internal cells. The presence of this "epidermis" gives rise to the smooth appearance of the sclerotium when viewed macroscopically. The sclerotia from culture resemble those found in nature but are slightly larger (Plate LI, figs. 3-5).

Cultures of *Sclerotium Oryzae* have been obtained from the Centraalbureau voor Schimmelcultures, Baarn, (Nakata's cultures), and from the Imperial Mycologist, Research Institute, Pusa, which on comparison have been found to be identical with cultures of the Ceylon fungus.

INOCULATION EXPERIMENTS

In 1912 Shaw (2) carried out inoculation experiments with *Sclerotium Oryzae* on paddy seedlings seven to ten days old and about three to four inches high. He grew seedlings on nutrient agar and made inoculations by placing a small piece of agar containing the hyphae of the fungus in a vigorous state of growth on the stem about an inch above the base of the plant. By this method he obtained 70 to 80% successes.

At Peradeniya inoculation experiments have been carried out on paddy seedlings in the laboratory and on older plants in clay pots and tins in the laboratory compound, simulating as far as was possible field conditions, in order to test the parasitism of the Ceylon fungus and to ascertain whether it resembled the Indian form in pathogenicity.

Seedlings

Seedlings in all the following experiments were raised from seed surface-sterilized by immersion in 0·1% aqueous solution of corrosive sublimate for five minutes, washed and then soaked in sterile distilled water for forty-eight hours. Unless otherwise stated inoculations were made by placing small pieces of culture medium containing the actively-growing fungus in contact with the plant, without wounding.

Experiment 1

Seedlings were grown in tubes on a substratum of plain agar. This method was found to be satisfactory on account of the ease with which contaminants could be avoided and the facility with which root examinations could be made during and at the termination of the experiment. Plugged culture tubes containing about 10 cc. of 1% agar were sterilized; after cooling, two paddy seeds were introduced into each of five tubes and the plugs replaced. The seeds germinated satisfactorily and after eight days shoots were from one and a half to three inches in height. At this stage eight seedlings in four tubes were inoculated with *Sclerotium Oryzae* about half-way up the shoot, the seedlings in the remaining tube serving as a control. In three days brownish discolorations were apparent at the points of inoculation and in eight days all the inoculated seedlings had collapsed. Sclerotia developed on the withered shoots and the fungus was observed to have attacked the roots of one seedling. The fungus was readily re-isolated in pure culture from the dead tissue of inoculated seedlings. The control seedlings remained healthy throughout.

Experiment 2

Paddy seedlings were grown on the surface of sterile agar in culture tubes as in experiment 1, two seedlings in each tube. Eight days after

sowing, the seedlings were all vigorous and the shoots varied in height from one and a half to three inches. At this stage the agar in seven tubes was inoculated with *Sclerotium Oryzae* after which a layer of one inch of sterile sand was added, followed by sufficient sterile water to moisten the sand. The cotton plugs were removed from the tubes at the time of inoculation. Two tubes containing seedlings treated similarly but without inoculation served as a control. Fourteen days later all seedlings in inoculated tubes had wilted and hyphae of the fungus were seen on the shoots above the level of the sand. On microscopical examination the roots of the infected seedlings were found to have been killed by the fungus ; hyphae were present within the root tissues and on re-isolation *Sclerotium Oryzae* grew in pure culture. The control seedlings were healthy throughout.

Experiment 3.

In this experiment an endeavour was made to allow actively-growing roots to come into contact with fungus growing in culture. For this purpose large boiling tubes, 10 inches long and $1\frac{1}{2}$ inches in diameter and containing about 50 cc. of $\frac{1}{2}\%$ agar, were plugged and sterilized. After cooling the agar was inoculated with sclerotia of *Sclerotium Oryzae* from culture. A layer of sterilized sand, two inches deep, was superimposed and moistened with sterile distilled water. Six paddy seeds were placed on the surface of the sand in each of five tubes, one of which had not been inoculated and served as a control. All the seedlings grew well ; the roots passed down through the sand and into the agar thereby coming into contact with the fungus. At the same time the fungus grew up through the sand and hyphae were observed on the surface of the bases of the shoots of the seedlings. After $3\frac{1}{2}$ months the experiment was concluded and 13 of the 24 plants in the inoculated tubes had been killed by the fungus there being six, four, two and one dead plants respectively in the four tubes. All the plants were examined and hyphae of *Sclerotium Oryzae*, proved by re-isolation, were found in the roots of six of the dead plants, while hyphae and sclerotia were found in the lower part of the shoots of all thirteen. Sections examined microscopically demonstrated that all the roots had come into contact with hyphae of the fungus but penetration was observed only in the roots of the six seedlings mentioned above. The plants which served as a control were healthy throughout.

Experiment 4

Small clay pots containing paddy soil were partially sterilized by pouring boiling water over them. Paddy seed were sown in the pots and eleven days later, when the seedlings were six to twelve inches high,

inoculations were made. Ten seedlings in one pot were inoculated and eight seedlings in another pot served as a control. Both the pots were placed in a dish containing water up to half their heights and covered over with a bell glass. Nine seedlings in a third pot were similarly inoculated and covered with a bell glass for twenty-four hours, after which time the bell glass was removed and the plants left exposed. In all the inoculations hyphae grew from the inocula and enveloped the stems but did not penetrate the tissues except in one seedling in which superficial discoloration occurred. The bell glass over the inoculated plants was removed after fourteen days. The seedlings were kept under observation for fourteen days more when they were carefully examined. The one infected seedling was penetrated only in the tissues of the outer leaf-sheath. The other seedlings were all healthy and normal.

Experiment 5

Paddy seeds were sown on soil in two pans made by dividing a kerosene tin longitudinally. Each pan contained about 300 seeds and was placed on a table in a well-lighted room. Inoculations were made in one tin by mixing a culture on maize-meal agar, five weeks old, in water and spreading it over the surface of the soil when the seedlings were eleven days old. Water was added to the second tin so that one inch of water covered the soil. A culture of the fungus was mixed with water and spread over the surface of the water in the tin when the seedlings were sixteen days old.

About ten days after inoculation in a large number of seedlings in the first tin discoloration of the stems at ground level was evident and the seedlings began to lose their green colour. Twenty days later a large number had fallen over and when examined it was found that nearly 95 per cent. of the seedlings were diseased. Hyphae had gained entrance by penetrating the seedlings at ground level. Numerous sclerotia were formed on the roots and for about an inch up the shoots, both superficially and internally. In the second tin a pale-brown discoloration appeared on the stems of some seedlings at water level about ten days after inoculation. Hyphae had penetrated the stems at this point. A month later about 75 per cent. of the seedlings had been attacked. In some, hyphae of the fungus penetrated the shoot at water level and caused a rot at that point, the lower portion of the plant being unaffected, while in others the roots were also infected. Sclerotia were formed in the roots of some plants and on the stems at water level. Hyphae were abundant in the diseased tissues.

Experiment 6

This experiment was similar to experiment 5 but the tins containing the plants were placed in the open. Seedlings in three tins were used for inoculation. In one tin the seedlings were grown in soil which had water an inch above soil level ; in the other two tins the water was at soil level. After three months 29 per cent. of the plants in the first tin were found to be infected. The fungus entered the plants at water level causing a light brown to purple-brown lesion ; in only a few plants were the roots affected. Sclerotia were present in the stems of some of the dead plants above water level. In the other two tins, *i.e.*, those tins in which there was no free water above the soil, 7·8 per cent. and 10·4 per cent. of the plants respectively were found to have been killed. Root infection had not taken place ; sclerotia were present on the outer leaf-sheaths of a few of the dead seedlings.

Older Plants

The pots used for experiments with older plants were earthenware, approximately cylindrical, 12 inches in diameter and 12 inches high, and glazed internally. The soil used was taken from a paddy field and was well puddled in the pots to simulate natural conditions.

Seedlings were raised in a tin and at the age of three weeks were transplanted into four pots prepared as above. In two of the pots sufficient water was added to allow of one inch to stand above the level of the soil, while in the other two pots water was added up to soil level. Eleven seedlings were transplanted into each pot. Three weeks after transplanting one pot of each treatment was inoculated with *Sclerotium Oryzae*, the others serving as controls.

Flooded pots—Inoculation was made by mashing up an actively growing tube culture of *Sclerotium Oryzae* in water and adding it to the water in the pot. A mulch of shredded dadap leaves was placed on the surface of the water to prevent the washing out of the inoculum by rain. A similar mulch was added to the control pot.

A few weeks after inoculation the shoots of six plants in the inoculated pot were dead. After three months the outer leaf-sheaths of all inoculated plants were dead. Infection had obviously taken place at or about the level of the water and greyish-brown discolorations were observed at that level. At the end of six months the original shoots of seven of the eleven plants were dead. Suckers had been produced from all these plants. In three of the plants the suckers were also attacked and killed, but the remaining four were unaffected although they were produced too late to have matured under field conditions.

A point of interest that was observed in regard to the production of suckers from diseased plants was that suckers, instead of developing from the root stock at the base of the shoot, grew from the first node above the soil. The remaining four plants, apart from the discoloration of the outer leaf-sheaths of the parent shoots noted above, were unaffected. Of the eleven plants only two died completely, the root systems of the remaining five severely attacked plants being free from infection. The control plants were healthy throughout.

Non-flooded pots—Inoculation was made by placing fragments of an actively growing culture of *Sclerotium Oryzae* on the surface of the soil. A mulch of shredded dadap leaves was then placed over the soil to prevent the washing away of the inoculum by rain. A similar mulch was placed in the control pot. The inoculation was made, as in the other series, three weeks after the seedlings had been transplanted into the pots.

After six months suckers or tillers had developed from the base of nine plants. Of these plants the parent shoots of four were dead and the sucker of one of these plants was also diseased. The suckers were all small and produced too late to mature under natural conditions. The control plants were healthy.

Infection of plants in this experiment resulted in extreme cases in the death of the plants and in others in local injuries and death of the shoot. One of the most marked effects was the production of abnormal tillers or suckers in infected plants.

DISCUSSION OF RESULTS OF INOCULATION EXPERIMENTS

The experiments described above gave results which indicate that under normal conditions of growth the parasitism of *Sclerotium Oryzae* is not very marked. Local infection of the outer leaf-sheaths may occur, but this does not extend unless conditions are suitable. Seedlings grown in unnatural conditions in tubes were infected in every instance when inoculated. Infection with *Sclerotium Oryzae* differs from that with *Rhizoctonia Solani* as described in Part I of this paper in that with the former fungus some root infection takes place. In the experiments described above it was noted that root infection took place only after the aerial portion of plants was infected and then not always. It is of some interest, however, to note that any root infection takes place since sclerotia produced within roots of plants under field conditions might add to the difficulty of eradicating the disease. This matter will be considered again later in the discussion of control measures. In the field as in the experiments described above root infection has been found to take place only in seedling plants.

The inoculation experiments have shown that infection is more extensive in plants which are not exposed to direct sunlight. With pots kept indoors 75 per cent. of the young plants in flooded pots and 95 per cent. of those in non-flooded pots were infected, while the figures for those outside were 29 per cent. in flooded pots and 7·8 per cent. and 10·4 per cent. in non-flooded pots. The difference is marked in both series but is greater in the non-flooded series, and it is to be presumed that atmospheric humidity is a factor of some importance in the parasitism of *Sclerotium Oryzae*.

Mortality was higher when young plants were inoculated and field experience bears this out. The resultant damage to the crop, however, is greater when older plants are infected. The common practice in Ceylon is to sow thickly, and it has been found that even with severe infection of young plants sufficient plants survive to give a full crop, the yield of which is probably but little less than would have been given by a greater number of more crowded plants. Where nurseries are affected then the direct loss of plants may be felt more keenly. In older plants the attack tends not to kill plants but leads to the formation of empty grains and of late tillers and consequent losses may be severe. It is of interest to note that no record has been made of infection both of seedlings and of mature plants in the same field in the same season. The reason for this is not obvious unless it may be attributed either to the non-recurrence of conditions favourable to the disease or to individual resistance to the disease. We have noted earlier in the paper an example of apparent variation of susceptibility among varieties and individual resistance to the disease may also occur.

VIABILITY OF SCLEROTIA

In Part I of this paper experiments were described in which the viability of sclerotia of *Rhizoctonia Solani* was tested under different conditions. Similar experiments have been carried out with sclerotia of *Sclerotium Oryzae* in order to determine if any natural factor could be utilised in controlling the fungus. Results are given below :

1. Sclerotia from a 54-day old tube culture on maize-meal agar were placed on air-dried paddy soil in the laboratory. The water content of the soil was 8·3 per cent. Individual sclerotia were transferred periodically to maize-meal agar tubes. Germination of the sclerotia was obtained up to 190 days after exposure, but after that date bacterial contamination occurred to such an extent that it was impossible to determine if germination took place.

2. Sclerotia from a 56-day old culture were buried one-half inch deep in moist paddy soil. The water content of the soil at the beginning

of the experiment was 18·5 per cent., the maximun water holding capacity of the soil being 39·9 per cent. Sclerotia germinated when removed from the soil after 133 days and transferred to maize-meal agar.

3. Pure tube cultures of *Sclerotium Oryzae* on maize-meal agar were sealed with paraffin wax. Sclerotia removed from these tubes after 600 days failed to grow when transferred to fresh culture tubes.

4. Sclerotia from a 73-day old culture were placed at the bottom of a dish of tap water three inches deep. Individual sclerotia were removed at intervals and their germinating power tested. Germination took place after 319 days but not after 385 days. The viability of these sclerotia may have been prolonged by the presence of an alga of the *Chlorella* type which made its appearance about a week after the immersion of the sclerotia.

5. Sclerotia kept in a corked specimen tube in the laboratory germinated after 525 days, but after 625 days bacterial contamination masked any germination that might have taken place.

6. Sclerotia from a two month-old culture were placed on air-dried paddy soil and exposed to the sun whenever possible—usually for six hours daily. The temperature was registered by a solar radiation thermometer, readings being recorded every hour. It was found that sclerotia exposed to the sun for 133 hours during a period of 26 days began to lose their viability which was completely destroyed after exposure for 145 hours on 28 days. The mean daily temperature during the 28 days varied from 47°C to 60·8°C., with an average of 59·2°C. The highest temperature recorded was 69·3°C.

The experiments show that (*a*) sclerotia remain viable on air-dried paddy soil in the shade for $6\frac{1}{2}$ months, (*b*) sclerotia remain viable when buried in moist paddy soil in the shade for $4\frac{1}{2}$ months, (*c*) sclerotia remain viable when submerged in water (in the presence of a green alga) for $10\frac{1}{2}$ months but that viability is destroyed in $12\frac{1}{2}$ months, (*d*) sclerotia remain viable under dry conditions *in vitro* for $17\frac{1}{2}$ months, (*e*) sclerotia are killed when exposed to direct sunlight for one month. It must be borne in mind that these figures were obtained under laboratory conditions but they are sufficient to indicate that none of the natural conditions at our disposal can be utilised readily in controlling *Sclerotium Oryzae* under field conditions.

GENERAL

Field examinations of diseased paddy and the inoculation experiments described in this paper have indicated that *Sclerotium Oryzae* may, under certain conditions, become a parasite of some importance on paddy. Infection of young plants results in the death of some plants

while others may recover, the ultimate effect merely being a check to their growth. As has been pointed out above, the effect of attack on young plants is not generally serious in Ceylon where the common practice is to sow more thickly than is necessary. Attack on older plants may be more severely felt owing to the large proportion of empty grains produced by infected plants.

The conditions which favour the incidence of the disease are not very clear. Certain points have been observed during the course of this investigation and a consideration of them may throw some light on the problem. The paddy attacked by *Sclerotium Oryzae* in Divulgaspitiya, Kurunegala, in January, 1926, mentioned earlier in this paper, comprised an area of about half an acre. When inspected in February of the same year, it was seen that unusaully wet conditions prevailed. Moreover, the disease occurred in a definite area starting from the point at which the outbreak was first observed and following the course of the flow of water. This suggested either that the fungus was transferred from the infected area to healthy areas by the flow of water or that something was present in the water in that area which rendered the plants susceptible to the disease. The inoculation experiment with older plants described above indicated that the presence of excess water favours the incidence of the disease, but at the same time plants under similar conditions near those affected in the area under discussion were not attacked by the disease. It may be of interest to note here that enquiries were made regarding this same field in September, 1927, and that we were informed that the disease had not recurred in that field nor in the adjoining ones ; that the fields were sown only once each year ; that the remedial measure suggested by us, viz., to burn the affected paddy plants *in situ*, had been adopted with apparent success.

We have discussed above the apparent variation in susceptibility in seedlings as shown in nurseries at Peradeniya. Imported Burma paddies were much more severely attacked than a local variety grown under similar conditions. That this susceptibility is inherent may be possible, but it is noteworthy that during subsequent seasons the Burma paddies have been grown successfully without marked infection. This of course may be attributable to the absence of *Sclerotium Oryzae* or to the absence of conditions favourable to attack. On the other hand, evidence has come to hand recently that a change of evironment may affect susceptibility. A pure line selection made at Peradeniya was given to a cultivator whose fields were not more than four miles distant from Peradeniya. The soil in which the paddy was planted was cultivated carefully and the young seedlings suffered from a severe attack by *Sclerotium Oryzae*. Adjacent fields containing the cultivator's own paddy were

not affected. The attack was, fortunately, of such a nature that sufficient plants outgrew the disease and a good crop resulted. This strain has shown no marked susceptibility to the disease hitherto, and it is not clear why it should have been attacked in this instance. It is possible that the fungus was introduced either with the seed or in the course of cultivation. The question of immunity and susceptibility appears to be rather complex and further observations are necessary before definite information can be obtained.

The experiments on the viability of sclerotia, described above, have unfortunately given no results of practical importance unless it is possible to utilise the prophylactic effects of sunlight. This would be difficult under field conditions since it has been shown that sclerotia remain viable for nearly a month when exposed to direct sunlight. A clean fallow of an infected area with periodical raking over of the soil might result in the death of the fungus. It would be unsafe, however, to recommend this as a practical measure for control since it has been shown that sclerotia may be produced in the roots of infected plants and such sclerotia would not be exposed to direct sunlight. Infected plants should be burned *in situ*. The straw from areas containing diseased plants should not be removed owing to the danger of transferring sclerotia of the fungus to uninfected soil.

CONTROL

Control measures may be summarised thus :—

1. Mark out areas containing diseased plants including a border of apparently healthy plants before harvesting. Such plants should not be harvested but should be burnt as soon as possible after the harvesting of the remainder.
2. Do not use varieties known to be susceptible to the disease in the area in question.
3. If detected early do not allow the passage of irrigation water through the fields containing diseased plants.

SUMMARY

1. The paper is the second of a series on the sclerotial diseases of rice in Ceylon.
2. The occurrence in Ceylon of *Sclerotium Oryzae* Catt. on paddy is noted and the etiology of the disease discussed.
3. The characteristics of the fungus in pure culture are described briefly.
4. Inoculation experiments are described on seedlings and on older plants.

5. Experiments on the viability of sclerotia under different conditions are described.
6. Conditions affecting the incidence of the disease and the occurrence of susceptible strains are discussed.
7. Notes on methods of control are given.

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EXPLANATION OF PLATES

Plate LI

Fig. 1. Sclerotia of *S. Oryzae* in hollow of culm of paddy. Nat. size.
Fig. 2. Pure culture of *S. Oryzae* on maize-meal agar. Nat. size.
Fig. 3. Section through sclerotium of *S. Oryzae* from nature $\times 270$.
Fig. 4. Part of section of Fig. 3 $\times 500$ (approx.)
Fig. 5. Section through sclerotium of *S. Oryzae* embedded in a maize-meal agar culture $\times 222$.

Plate LII

Fig. 1. Type of hyphae found at edge of glucose agar culture medium $\times 950$.
Figs. 2-5. Types of hyphae usually occurring in culture $\times 950$.
Figs. 6, 7. Thick-walled, olive brown, chlamydospore-like cells in Dox agar culture $\times 950$.

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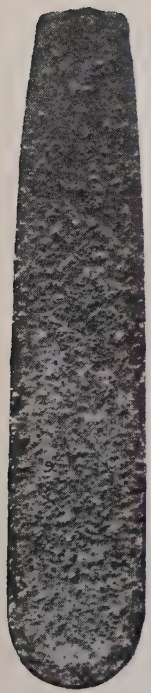

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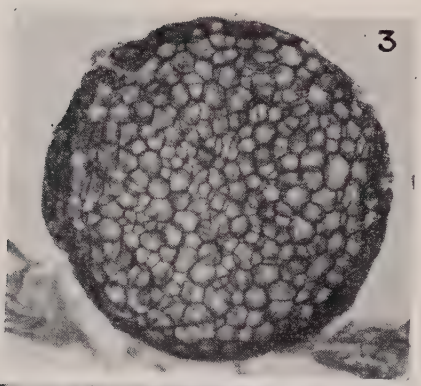

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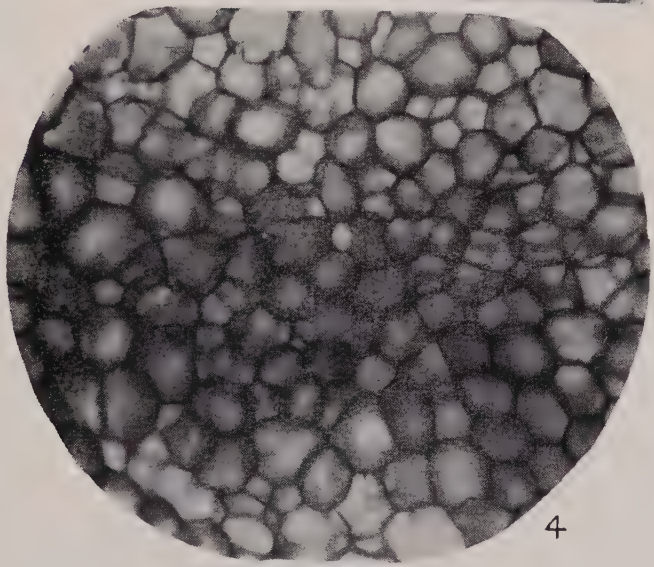

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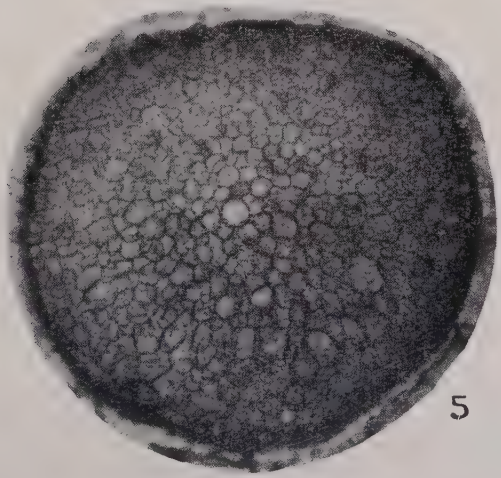

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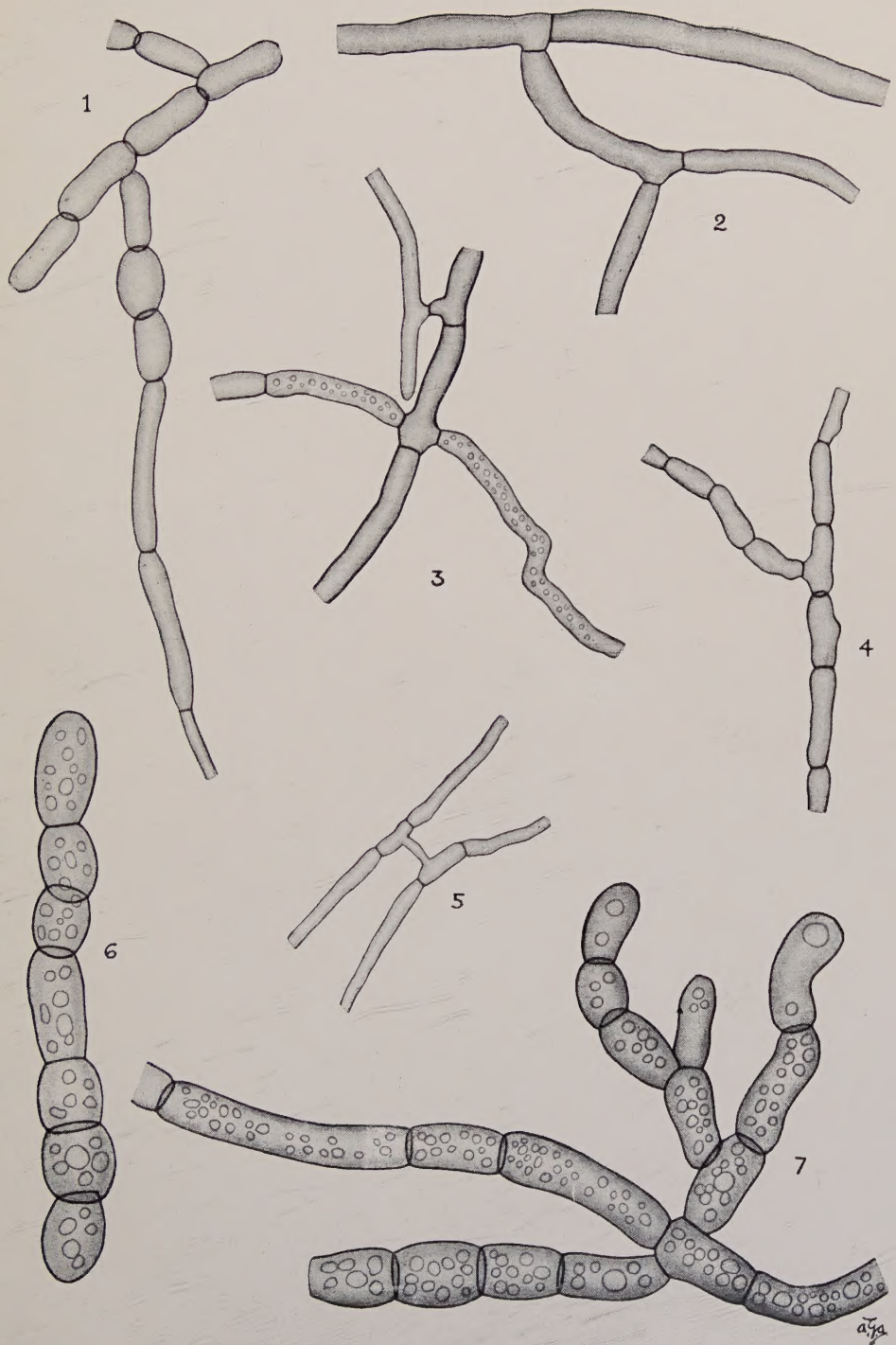
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EDITORIAL NOTE

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